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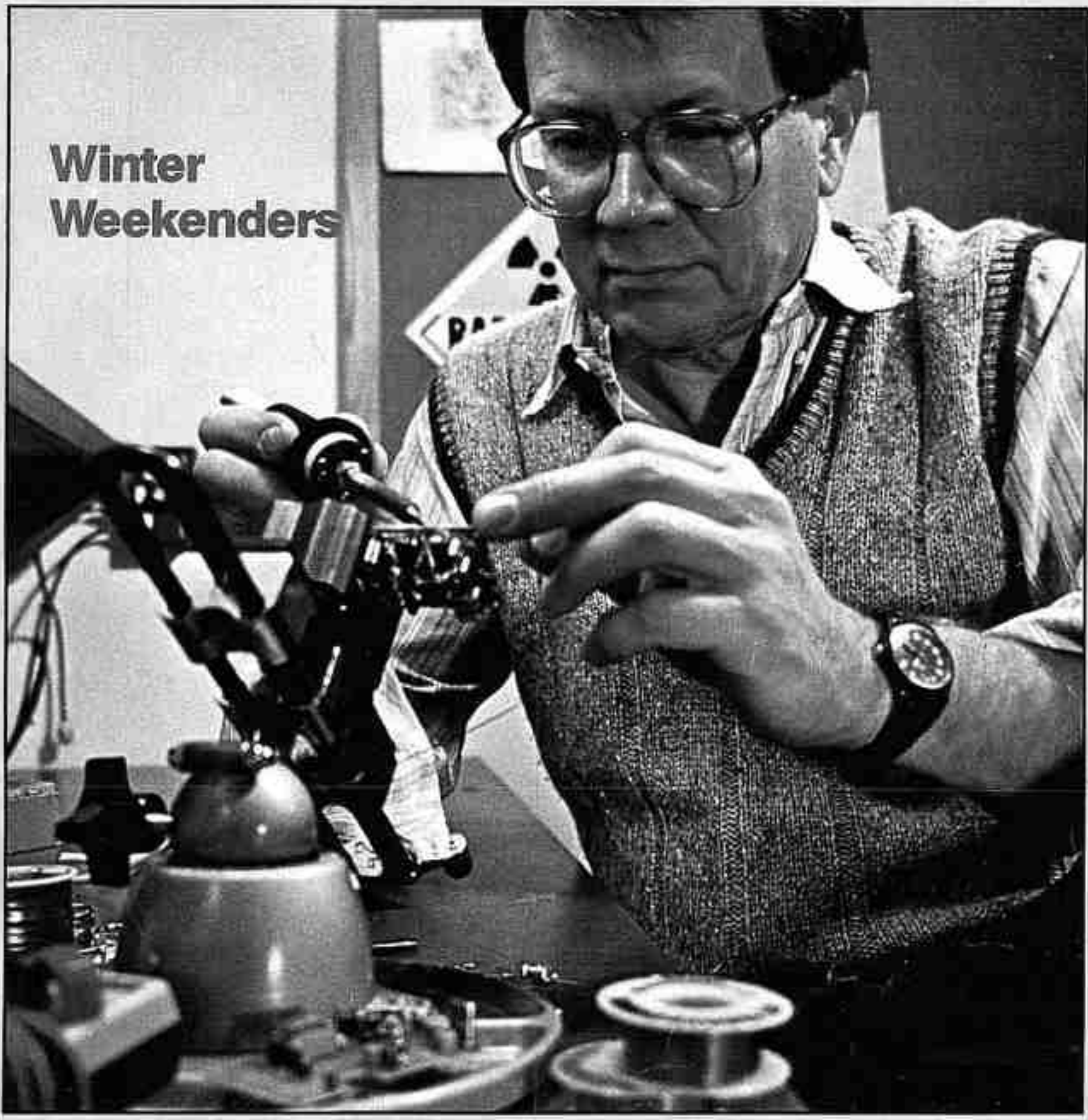
SPECIAL CONSTRUCTION ISSUE

HAM RADIO

NEW



Winter Weekenders

HAM RADIO

JANUARY 1989

volume 22, number 1

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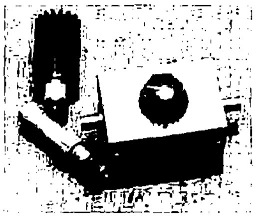
FEATURES



K4IPV, page 83

NH6N, page 20
N6JH, page 88

See page 31 for the winners of November's handheld radio contest.

DEPARTMENTS

BACKSCATTER

RADIO SPECTRUM POLLUTION

A recent editorial in the *Boston Globe* about radio spectrum pollution and its effects on the field of Radio Astronomy hit a very familiar chord. Radio spectrum pollution is a problem that is shared by far more than those in the field of Radio Astronomy. Almost all users of the radio waves, both passive (those who listen) and active (those who transmit a signal) have suffered from noise pollution of one form or another.

Due to the very nature of their science, Radio Astronomers are far more susceptible to noise problems. The signals that they are receiving are so weak, that it's nearly impossible to describe to the layman the technology that must be used. It may be hard to believe, but a car passing a receiving point at the wrong time could invalidate weeks of work.

The *Globe's* editorial suggested that the solution to the problem would only cost a few dollars. That is, unfortunately, incorrect. It went on to say that Congress should explore whether legislation may be necessary to encourage, or even require, manufacturers to install filters that would reduce the noise pollution caused by electrical equipment of all kinds.

Interference problems have plagued Radio Amateurs and other radio users for years. Studies conducted by a number of trade organizations have shown, time and time again, that interference caused to home TVs, radios, and VCRs, is caused by poor design in these devices and a lack of simple, easy-to-install filters! The manufacturers have been unwilling to incorporate changes due to the cost — a $1 fix times millions of devices totals up to millions of dollars — that the consumer will ultimately pay for. To me, the thought that they will install "noise filters" to protect Radio Astronomers is ludicrous.

Radio Amateurs spend hundreds of dollars engineering their stations to meet FCC specifications. Even so, they are still blamed for interference to consumer electronic devices — a problem that is created in the unit itself. Attempts by Radio Amateur lobbyists to get FCC or Congressional relief, have so far been unsuccessful.

While I would like to believe that there is a simple solution to the problem, it will be far more difficult to effect. The utopian view that Congress can solve all problems is just a dream. The answer lies, instead, in proper design and manufacturing techniques, along with firm standards of performance for consumer electronic devices mandated by the FCC.

J. Craig Clark Jr., N1ACH

COMMENTS

Challenge your knowledge

Dear HR

I've been a HR subscriber since my return from Vietnam in late 1968. You have always given me the kinds of technical articles that were on the leading edge of technology. Both in my hobby (ham radio) and in my former occupation (junior college teacher), I have been able to draw upon your magazine for a source of ideas, challenges to my expertise, and enjoyment in the challenging field of electronics. I like the idea of "Elmer's Notebook" to help newcomers discover what some (or most) of us internalized long ago.

To use a worn, trite phrase, "keep up the good work."

Richard B. Bridges, WB5GSA,
APO New York 09757

Technical competence compromised

Dear HR:

For the past several days the Cable News Network has been showing interviews with and comments about a survey of Americans concerning their knowledge of geography. Almost nobody knew the locations of Central America or Massachusetts. Very, very few knew the population of the United States. The terrible ignorance is appalling and immediately brings the politicians to their rostrums, snarling, "We MUST do something about this!"

And now I see more letters whining about being given MORE beneficial communication handouts. Could it be that the one, basic and fundamental reason that these people cry for easier examinations (or none at all) is that there is a provable and colossal ignorance loose in the land? Is it necessary to have easier test standards because hardly anyone can sucessfully pass an examination that used to be routinely given to high school teenagers thirty years ago? When I passed my Class B examination and thirteen word per minute code test 41 years ago, was I more intelligent than some college level student of today? Perhaps.

Let me point out that Amateur Radio is not a service to the average person on the street. Amateurs are licensed "in the public interest" and let us not allow the same word-twisting go on here as happens with the First Amendment. We assist in fire and flood, tornado and earthquake — we do not order pizzas or pass the word to your secretary that you've decided to have that extra martini. By all means, get a cellular telephone — that's just what they are for. The FCC experiment on 27 Megacycles to allow the citizenry to have access to their own, unmolested HF communications speaks loudly for itself. Those of you who believe that the future of Amateur Radio stands in harm's way are probably right. But is the answer to heap the spectrum with electronic effluvium in an attempt to disguise a little bit of communication knowledge — or to raise the level of technical competence to a point where it can be recognized and rewarded?

I don't believe that one would have to hire the best market survey company in the country to discover that a majority of amateurs find $2500 a rather steep price for a piece of ham gear — entrance level or not! I started out with a single 6L6 and a surplus crystal. But not today! Your kid doesn't want a Model-A, he wants a Mercedes Benz! The makers of soldering irons are going the way of the buggy whip manufacturers. Change the motherboard! It's much more of a challenge to break laws, social and moral — and all of us tired old people sit and wonder why the young people aren't just flocking to join the Amateur Radio ranks. Better start a stamp collection, brudder.

Joe Weite, KH6GDR,
Makakilo, Hawaii 96706

Latest issue... Great!...but..

Dear HR:

Hey guys! Great new September issue, but...I can't read the parts list on page 20 or LOTUS information on page 32 (fig. 2 and 3). Any chance of seeing it in larger print?

Thanks and good luck.

Sam Popkin, K2DNR,
Tucson, Arizona 85747

Full size copies of programs and parts lists are available for an SASE.
Ed.

Is zone 29 rare in contests?

Dear HR:

I enjoy giving zone 29 to United States stations during contests where zones count as multipliers.

However, over the past few years during each contest I have noticed that nearly every time I call a strong W station, by the time I give my callsign, he is calling CQ contest again, without having made a contact.

Perhaps my Australian drawl or accent puts stations off?

Honestly, most stations do not allow *time for me to give my callsign.*

If I do make a contact, most U.S. stations are very happy to have zone 29 as a new multiplier and they say so. So, please all you contest stations look out for the VK6 and leave enough time between calls.

By the way, there are only about 900 VK6 stations altogether and probably 4 or 5 active contesters!

Graham Rogers, VK6RO,
Ferndale, Western Australia

AN NE602-BASED QRP TRANSCEIVER FOR 20-METER CW

By Rick Littlefield, K1BQT, Box 114, Barrington, New Hampshire 03825

A complete QRP station that slips into your coat pocket

I've recently seen several small projects using the Signetics NE602 Gilbert Cell mixer.[1,2] I first used the NE602 in the "Micro-20 Receiver," a simple 20-meter superhet.[3] Additional experience and helpful feedback from other builders encouraged me to carry my exploration a bit further. Here's a complete QRP 20-meter transceiver which presses the NE602 into service as a transmit mixer.

Three modules contain the transceiver circuitry. The 3.25″ × 1.7″ receiver board is a new version of my original "micro-20" project, with several refinements for improved performance. The transmitter board is the same size as the receiver and is designed to deliver the QRP "legal" limit of 5-watts output. Other transmitter features are: high-Z keying, semi-QSK T/R switching, and provisions for adjustable CW off-set and sidetone monitoring. A CW filter board narrows receiver i-f and audio passbands for serious CW work. All of this fits into a 1.75″ × 4.0″ × 4.0″ Ten-Tec TG-type cabinet.

Receiver description

The receiver schematic is shown in **fig. 1**. This is a conventional single-conversion design incorporating some of the more desirable aspects of past projects.[4] The theory of operation has been presented elsewhere, but several refinements deserve mention. First, RF bandpass filter L1,L2 has been changed to improve out-of-band rejection. Second, the i-f was changed from 9 to 10 MHz. This lets you use inexpensive computer-clock crystals for the i-f filter and BFO. I added an optional BFO modification to ensure sufficient BFO tuning range when these crystals are used.

In the audio/AGC section, I dropped S-meter circuitry in favor of adding a trimpot for AGC threshold. Along the same line, I adjusted AGC drive to eliminate overshoot on extremely strong signals. Good AGC performance is important because receive circuitry remains "live" during transmit to monitor the CW signal.

The NE602 operating voltage was reduced slightly to improve operating characteristics, and VFO tank L3 was changed to resonate in the required 4.0-MHz range. Finally, I reconfigured the VFO tuning to cover only the bottom 100 kHz of the band.

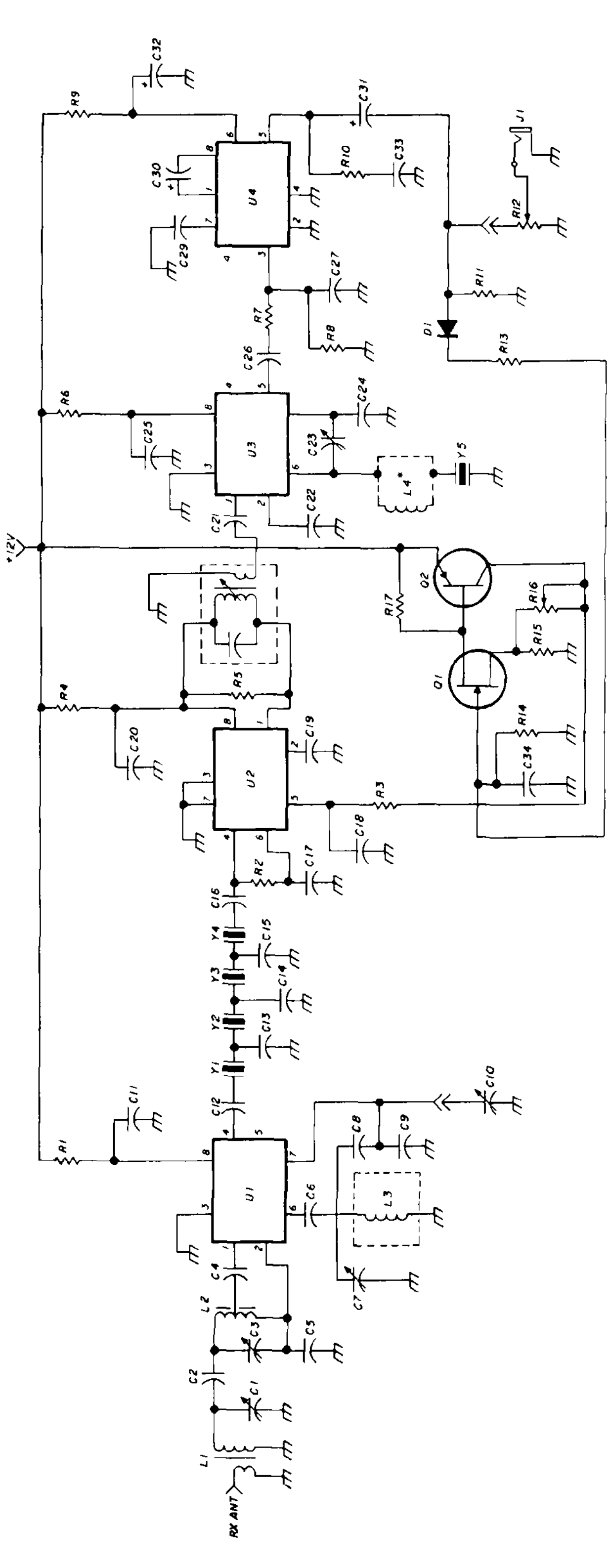
Transmitter description

Figure 2 shows the transmitter module. This board contains RF circuitry and switching for semi-QSK operation. Transmit mixer U1 samples the 4-MHz VFO signal generated in the receiver and mixes it with an internal 10-MHz oscillator to produce 14-MHz output. Transmit-offset is set by netting the 10-MHz LO. This arrangement eliminates the need to shift receiver BFO frequency during transmit and allows the receiver to be used as a sidetone monitor.

Keying is accomplished by switching the 12-volt supply line to U1. This is done by Q1, a DC switch which also activates relay controller Q2. Q1 presents a high-Z load to the handkey or keyer. Q2 functions as an FET relay driver for K1. An RC circuit on the gate of Q2 sets semi-QSK hold time. The values specified provide a delay of about 1 second. They can be adjusted if you wish. K1 supplies +12 volts Vdc to Q3 and Q4 during transmit, and switches the antenna.

Q3 functions as a tuned-output buffer/driver which boosts U1's output to the required level for driving Q4. Class-C final amplifier Q4 delivers 4.5-5.0 watts output into a 50-ohm load with a Vc of 12 volts (somewhat

FIGURE 1



Schematic of transceiver receiver section. Component values are given in the receiver module parts list.

PARTS LIST

Receiver module

Capacitors (all monolithic capacitors are 50 volt)	
C1,C2,C23	60 pF trimmer
C2	2.2 pF NPO
C4,C21	0.001 μF monolithic
C5,C6,C11, C17,C19,C20, C22,C25,C29, C33	0.1 μF monolithic
C7	8 pF NPO trimmer
C8,C9	330 pF NPO
C10	50 pF variable, VFO main tuning
C12-C16	(5) 100 pF/100 volt silver mica
C18	0.01 μF monolithic
C24	47 pF NPO
C26,C34	1 μF monolithic or electrolytic
C27	0.068 monolithic or equivalent
C30	10 μF/12 volt tantalum dip or electrolytic
C31,C32	100 μF/12 volt electrolytic
Inductors	
L1	20 turns no. 28 on T30-2, 1-turn link on cold end
L2	20 turns no. 28 on T30-2, tap 7 turns from cold end
L3	57 turns no. 36 on 1/4" form (no slug) in 13-mm can
L4	(optional) 10 or 15 μH miniature choke
T1	10.7-MHz 10-mm i-f transformer, green core
Resistors (all 1/4-watt)	
R1,R6,R7	2.2k
R2	390
R3,R5,R17	10k
R4	100
R8	47k
R9	22
R10,R11	15
R12	500-ohm linear pot with switch
R13	33k
R14	2.2 meg
R15	1k
R16	10k miniature trimpot
Semiconductors	
U1,U3	NE602
U2	MC1350P
U4	LM386
Q1	MPF-102
Q2	2N3906
D1	1N914
Y1-Y5	10.000-MHz series resonant (100-Hz match)

greater output with a Vc of 13.8 volts). The PA collector tab is mounted to the transceiver case for cooling. T1, a 4:1 balun, transforms the output of Q4 to 50 ohms. Harmonic filtering is provided by a 5-element low-pass filter.

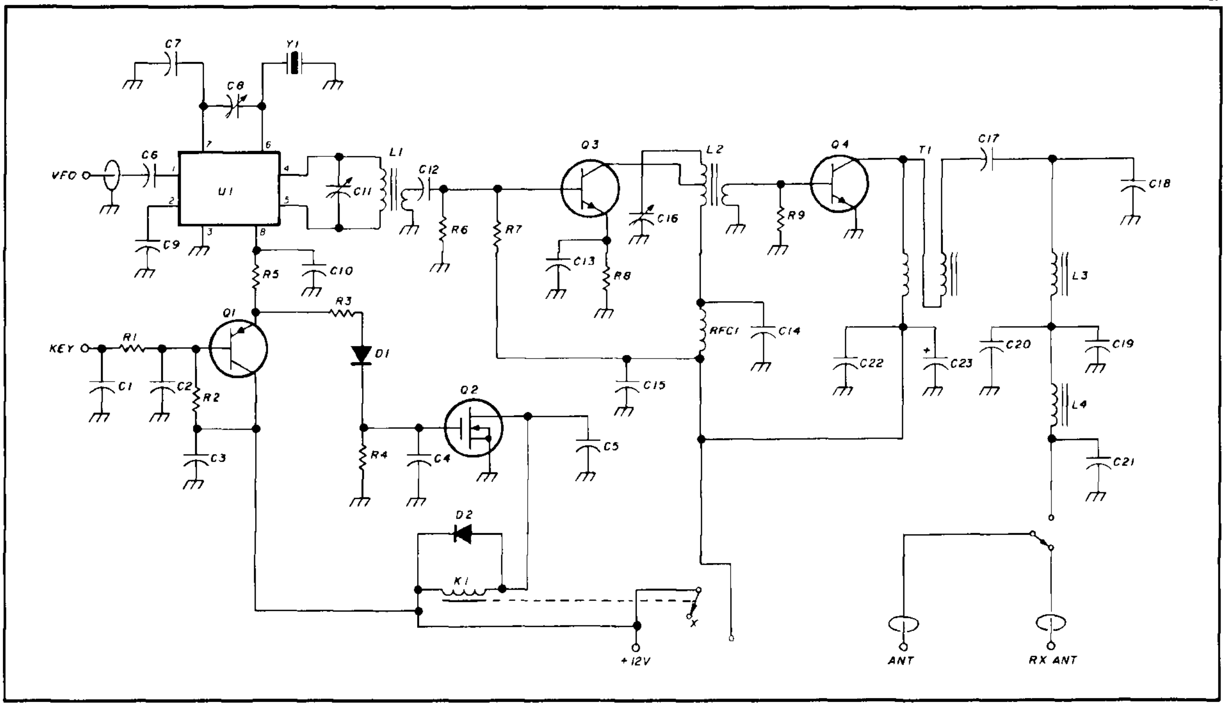
Filter description

The CW filter module, shown in **fig. 3**, actually houses two discrete circuits. The first is a 4-pole Cohn crystal bandpass filter identical to the one prescribed for the receiver. This connects in place of C21 on the receiver board and acts as a "post filter" for the i-f amplifier. The second element is a two-stage 700-Hz active bandpass filter installed between the product detector and audio amplifier (in place of C26). Distributing filtering throughout the system this way increases selectivity and, at the same time, reduces broadband noise generated in each stage. It also reduces the opportunity for ringing. The result is a very quiet and tight receiver — two important qualities for chasing serious DX, or pulling fellow QRP operators through noise and QRM.

Construction

Because this project employs two identical four-pole Cohn bandpass filters, your first task is to obtain eight 10.000-MHz crystals that resonate near the same frequency. Design bandwidth for the filter is about 1 kHz, so your matched set should resonate within 100 Hz of each other in a test oscillator (tolerance is 1/10th the desired bandwidth.)[5] The exact frequency of oscillation isn't critical, as long as the crystals you select cluster

FIGURE 2



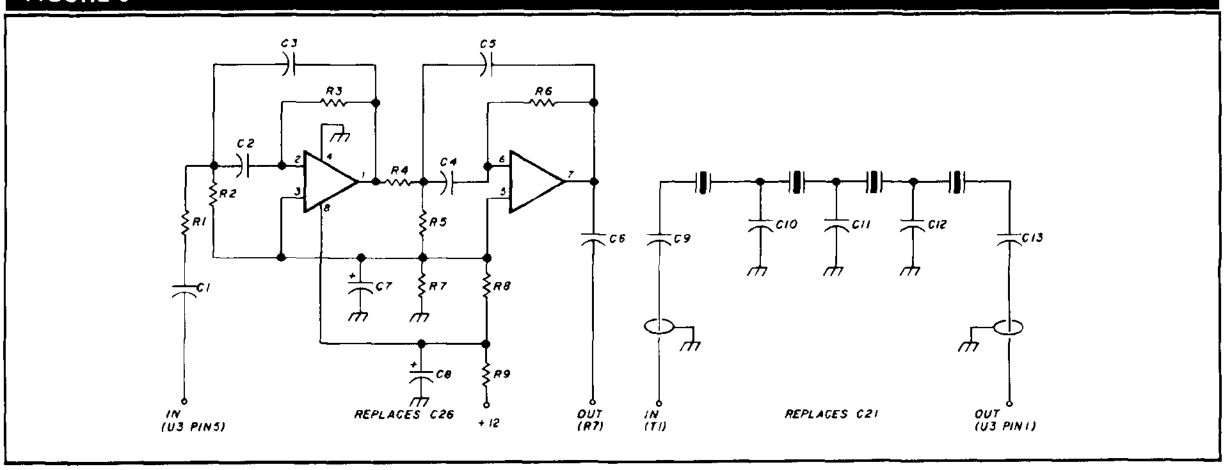
Schematic of transceiver transmitter section. Component values are given in the transmitter module parts list.

around *some* center frequency. It's my experience that 20 crystals from the same batch will yield eight close enough to do the job. If your crystals are spread over a wider range, the filters will work — they'll just be a bit broader.

All board layouts assume 1/4-watt resistors and monolythic bypass capacitors with 0.1″ lead spacing. Board layout is tight, but construction is straightforward. If you have the proper tools plus some experience working on contemporary solid-state equipment, you should have no trouble building this rig. It's good practice to dope all toroid inductors and secure them to the board with glue. Double-check part locations and component polarities.

The receiver parts layout is shown in fig. 4. The most difficult job is winding VFO inductor L3; no. 32 wire is thin, and may break if pulled too tightly. I wound this coil on a 0.25″ plastic form (FM receiver type) with the slug removed. It helps to mount the form before winding, and to secure windings in place immediately with clear nail

FIGURE 3



Schematic of transceiver CW-filtar section. Component values are given in the CW-filter module parts list.

PARTS LIST

Transmitter module

Capacitors	
C1,C2,C3, C5,C9,C13, C14,C15,C17, C22	0.1 μF/50 volt monolithic
C4	1 μF/50 volt monolithic
C6	15 pF NPO
C7	47 pF NPO
C8,C11,C16	60 pF trimmer
C10,C12	0.01 μF, monolithic
C18,C19,C20, C21	220 pF silver mica
C23	10 μF/12 volt tantalum dip or electrolytic
Inductors	
L1	20 turns no. 28 on T30-2, 2-turn link on center
L2	20 turns no. 28 on T30-2 center tapped, 2-turn link on cold end
L3,L4	12 turns no. 24 on T37-2, spread over 80 percent of form
T1	10 turns bifilar no. 24 on FT37-81
RFC1	12 turns no. 28 on FT23-43
Resistors (all 1/4-watt)	
R1	47k
R2,R3	10k
R4	330k
R5	1.8k
R6	470
R7	2.7k
R8	47
R9	33
Semiconductors	
U1	NE602
Q1	2N3906
Q2	BS-170 (Radio Shack)
Q3	2N2222A
Q4	MRF-476 (Motorola)
D1,D2	1N914 switching diode
Y1	9.9985-MHz series resonant, 0.2″ lead spacing
Miscellaneous	
K1	DPDT flat-pack 12 volt relay (Radio Shack)
	TO-220 insulated mounting kit (Q4)

polish. There are mounting holes for a CirKit 13-mm shield can (0.5″ × 0.5″ × 0.75″), but other shields will work.

You must install two jumpers on the back side of the receiver board. Fabricate TP-1 (test pin) from any discarded lead end. It's good practice (though not essential) to tie the cases of Y1-Y4 together with a common ground lead once they are soldered in place. Remember to omit C20 and C26 if you plan to install the external CW filter before initial testing.

Figure 5 shows the transmitter layout. A cutout is nibbled in the board to permit access to Q4's tab mount. To install Q4, first nip off the center lead (collector), then mount the device on the back side of the board as shown. Next, temporarily install a solder lug on the collector tab: This will help when you mount T1.

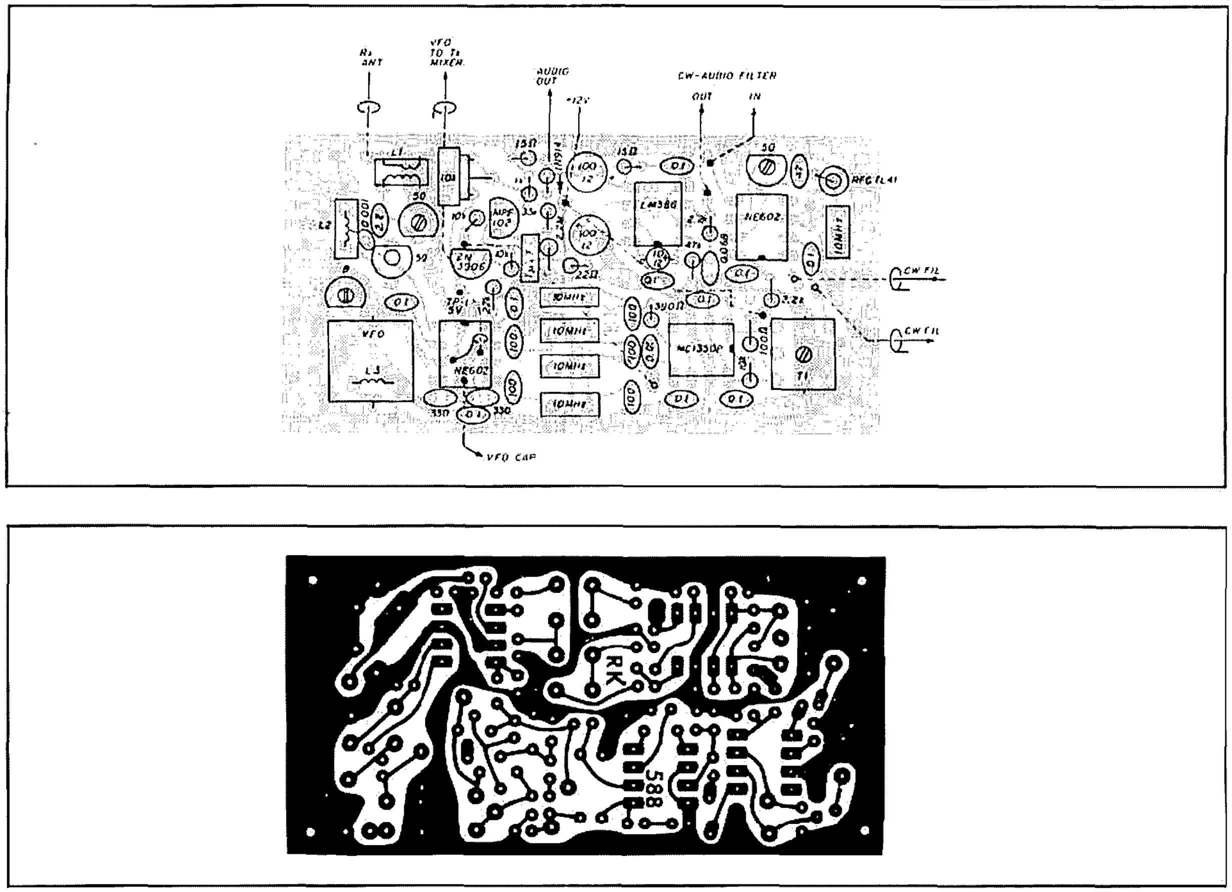
Install four jumpers on the back side of the module. Omit the jumper from K1 to C23 if you plan to run the PA directly off a 13.8-volt power source (Q4 is a class C stage, so Vc can remain connected during receive). Also, note that R9 is tack-soldered to the back side of the

PARTS LIST

CW Filter Module

Capacitors	
C1,C6	1 μF/50 volt monolithic or 1 μF/12 volt electrolytic
C2-C5	(4) 0.001, 1 percent 100-volt mylar film or equivalent
C7	10 μF/12 volt tantalum dip or electrolytic
C8	47 μF/12 volt electrolytic
C9-C13	(5) 100 pF/100 volt silver mica
Resistors (all 1/4-watt, 5 percent)	
R1,R4	680k
R2,R5	74k
R3,R6	1.8 meg
R7,R8	22k
R9	1k
Semiconductors	
U1	1458 (op amp)
Y1-Y4	(4) 10.000-MHz series resonant (100-Hz match)

FIGURE 4



Component placement and pc board layout for the receiver.

board. Because the VFO line connects to the front side of the board, you must install a pin in the hole next to C6.

Constructing the CW filter module is easy — just follow the parts layout in **fig. 6**. If you substitute something other than 1 percent mylar-film precision capacitors for C2-C5, it is *critical* that you screen them with a capacitance bridge and select four values within 1 percent of each other. C9-C13 must be 100-volt silver micas; larger 500-volt types won't fit on the board.

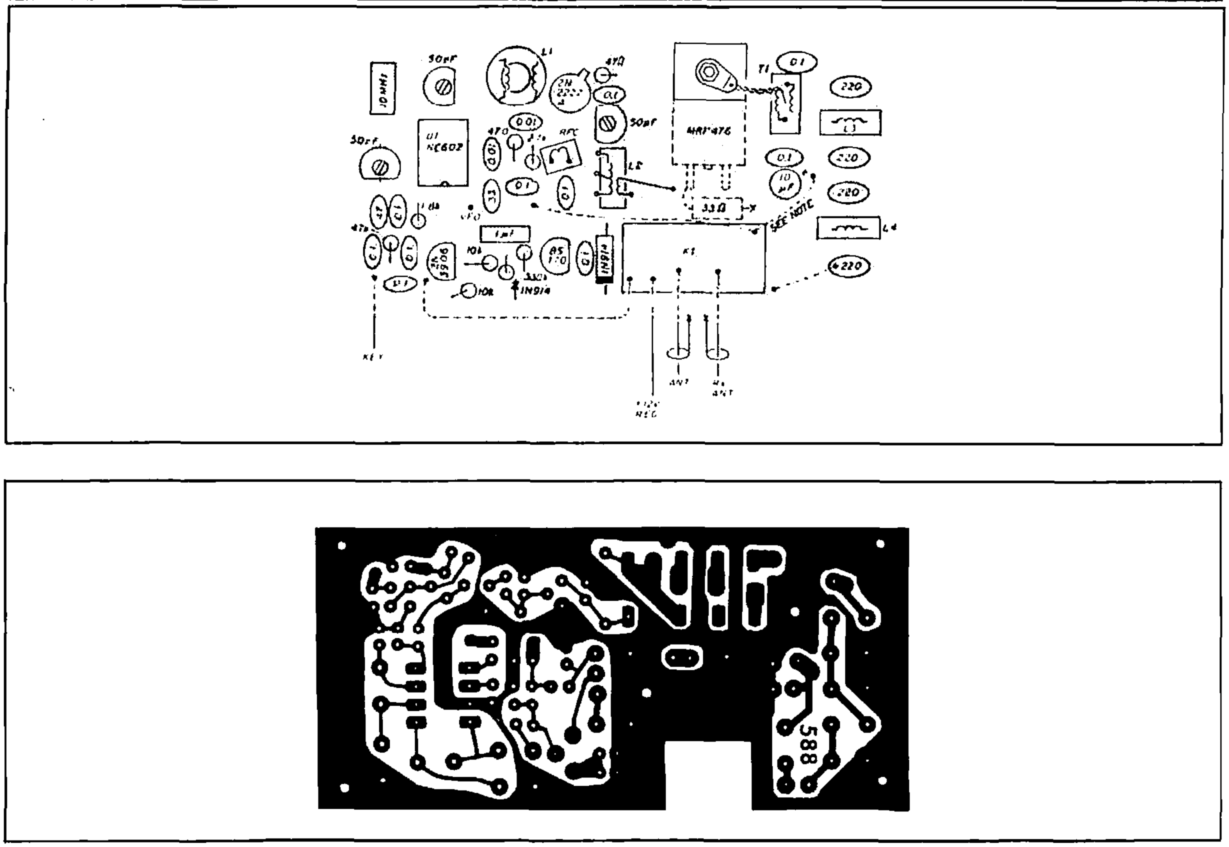
Packaging

Any box can be used to house the transceiver. I built mine into a Ten-Tec TG box; **fig. 7** shows the layout. My first prototype sported several switches for various functions, had an S-meter, plus an array of status LEDs. While these options were simple to add, I found they contributed little to operation and needlessly complicated internal wiring. For my final layout, I opted for utter simplicity — a volume control and a tuning knob. One of my prototypes does have a small speaker built into the top. This is nice for casual listening, but when I settle in for some serious operating, the 'phones go on!

Choosing the right VFO tuning capacitor is important; it's the control you'll use most. Radiokit[6] sells a 50-pF ball-bearing capacitor with a built-in 6:1 drive perfect for QRP projects like this one. You can attach a simple pointer or concentric dial plate to the inner shaft for a frequency indicator. I recommend installing this — and all cabinet-mounted components and parts — before mounting the boards. Also, wire the 7812 voltage regulator.

Mount the transmitter module to the back panel of your cabinet with 3/16″ spacers and no. 4-40 hardware. This provides sufficient clearance for the MRF-476 to seat between the board and back panel. Six mounting points (with four in the PA section) ensure a respectable RF ground for the single-sided pc board. Mount the receiver to the bottom of the case on similar spacers. Leave enough room on the right-hand side for mounting the CW filter module. This is positioned vertically and held in place by a stiff solder lug bent to form a 90-degree bracket. Note the location of the 7812 regulator — all heat-generating components are kept as far from VFO circuitry as possible to ensure stability.

FIGURE 5



Component placement and pc board layout for the transmitter.

Interconnections carrying RF or i-f signals use miniature shielded cable. (Spiral-wound lavalier microphone cable is especially easy to work with.) *Remember to ground shields at one end only.* The shielded lead between the receiver VFO and transmit mixer adds capacitance to the VFO's LC circuit. Keep this as short as possible (ground shield at the receiver end). The keying line and all audio lines are unshielded. Use stiff bus wire to connect the receiver module to the VFO capacitor.

Alignment

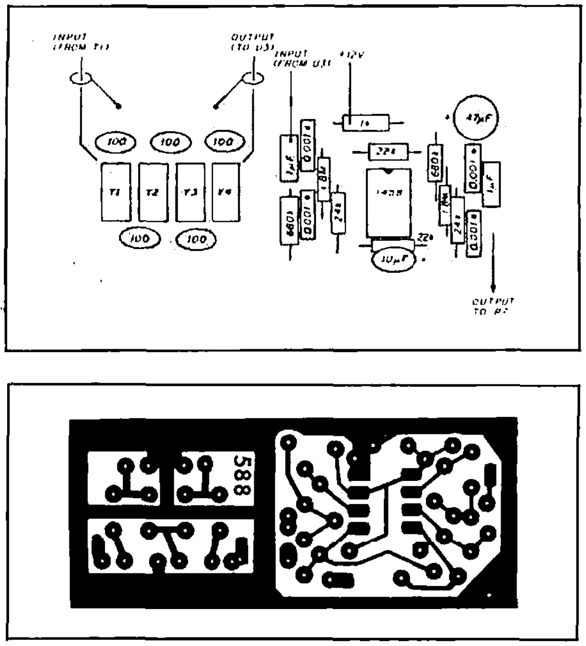
Set up the receiver. Connect a voltmeter to TP-1, and set trimpot R16 for a reading of 5 volts. Next, check the VFO and BFO for oscillation (using a general coverage receiver or counter). Adjust VFO calibration (C7) to cover from 4.0 MHz to between 4.070 and 4.1 MHz (20-meter CW range). To obtain this, you may need to substitute or add fixed capacitance. Set the BFO (C23) for 9998.5 — about 1.5 kHz below the filter's center frequency. This ensures acceptable rejection of the unwanted sideband. When the BFO is set, adjust T1 for an audible peak in background noise. Finally, connect an antenna or terminated signal generator, and peak C1 and C3 for maximum sensitivity.

To tune the transmitter, connect a power meter and dummy load, and key the transmitter. Set C8 for an audible sidetone of around 1.5 kHz. Finally, adjust C11 and C16 for maximum output. Tuning should be smooth and sharp, without erratic peaks or other indications of instability.

Now make one final adjustment. In theory, offset should equal the audible sidetone frequency (i.e., the beat between the two 10-MHz LOs). In fact, the NE602 VFO has a habit of pulling a few hundred Hz during transmit — probably due to a load change when the circuit is keyed. Although unsettling, this effect is apparently harmless — there's no audible chirp. To compensate for the shift, send a string of dashes on your station transceiver and tune it in on the QRP rig (700 Hz note). Then key the QRP rig and adjust C8 for a corresponding 700-Hz note on the station transceiver. My sidetone note is around 1.5 kHz with offset adjusted to 700 Hz.

Before concluding, I should add a word about filter terminations. Theoretically, Cohn filters must be terminated at their characteristic impedance to provide optimal response. In practice, I find the impact of a mismatched port often looks worse on the scope than it sounds on the radio. By way of illustration, one of my

FIGURE 6



Component placement and pc board layout for the CW filter.

transceivers has resistively terminated filters and the other doesn't. In side-by-side comparisons, I can't hear the difference. Nevertheless, if you wish to go the extra step, here's how. First, take two 470-ohm resistors and carefully solder a 0.01 monolithic capacitor in series with each. On the back of the receiver board, tack-solder one of these from pin 4 of U1 to ground. On the CW filter board, tack the other from the output side of the filter to ground. Now, take a third 470-ohm resistor and tack it from the input side to ground. That's all there is to it.

Conclusion

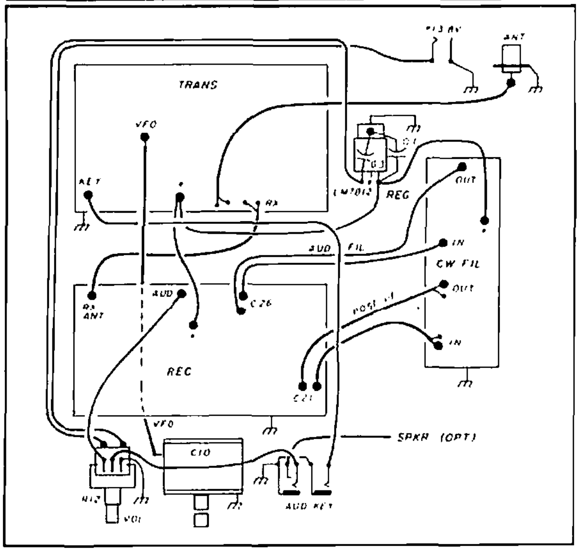
I owe special thanks to several builders who have written and shared their experiences with the NE602. Ed Pacyna, W1AAZ, deserves special credit for some of the information offered in this article. I also want to thank Radiokit for their ongoing support and encouragement.

Although billed as a double-balanced mixer, be aware that the NE602 is not "state of the art" for HF applications. It's a high-Z device with lots of gain and a third-order intercept of only − 15 dBm, so it's prone to stray pick-up and occasional symptoms of intermodulation distortion. On the other hand, the NE602 has many attributes. It has a very low noise figure, needs no external LO circuitry and a minimum of external parts, comes in a small package with low power consumption, and is inexpensive. For the QRP microphile, these are very attractive pluses!

When it comes to actual operation, the rig itself is a lot of fun to use. Interference caused by overload is minimal and rarely a problem. I especially like having the built-in creature comforts of a good AGC, CW filter, sinewave sidetone, and semi-QSK switching (as opposed to full QSK). On the transmit side, running a full "QRP gallon" (5 watts output) ensures plenty of action. (My first on-air test landed a QSO with Nick, UV3DN, just outside of Moscow.) Best of all, the transceiver's small size means you can set it up anywhere. I presently have one in the office (a benefit of owning the company). My business partner refers to it as "the magic paperweight we use to talk to the Russians." People think he's kidding.

A complete parts kit (including pc boards and enclosure) is available from Radiokit for $124.95. A set of pc boards is $8.95. Ed.

FIGURE 7



Board placement within the enclosure.

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2. John Dillon, "The Neophyte Receiver," *QST*, February 1988, page 14.
3. Rick Littlefield, K1BQT, "The Micro-20 Receiver," *73*, February, 1988, page 28.
4. Rick Littlefield, K1BQT, "Compact 20-meter Travelradio," *ham radio*, June 1987, page 29.
5. Wes Hayward, "Designing and Building Simple Crystal Filters," *QST*, July 1987, page 24.
6. Radiokit, Box 973, Pelham, New Hampshire 03076.

Article A HAM RADIO

THE WEEKENDER

Going digital

Like many hams, I'd been eyeing the numerous articles and gadgets designed to lead us into the modern century and go digital. Upgrading to digital involved spending a considerable sum of money, because I really couldn't do it at all without a computer and a terminal node controller (TNC). My engineering training drove me to research the abundant literature, try out each potential choice, and then look for the best price.

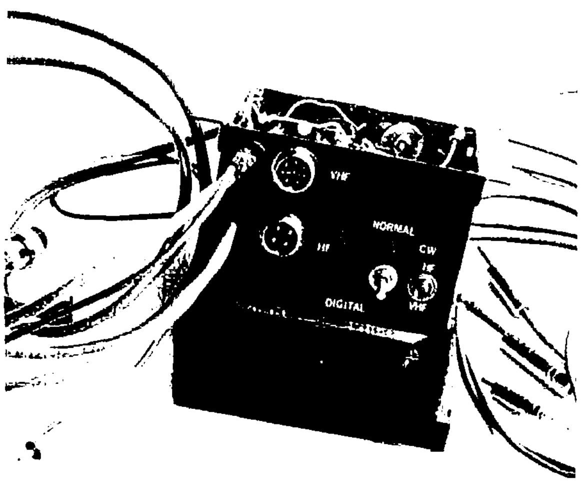
COMPUTER SHOPPER Magazine offered the widest possible selection of inexpensive computers, usually IBM clones. Armed with this information, I made a foray into the numerous computer stores in Silicon Valley and found exactly what I needed at a surprisingly low price.

A display at a recent ARRL convention featured all of the TNCs operating side by side. For various reasons, I liked the AEA PK 232 PAKRATT best and bought it.

Back home I was anxious to hook up the thing to my VHF and HF rigs and get on the air. As it turned out it's not like hooking up a toaster. You have to acquire or fabricate an RS-232 cable to connect the PAKRATT to the serial port of your computer. In the instruction book, AEA explains that only 10 of the available 25 pins in the socket/cable should be connected. You also have to make up the two special cables that link the two rigs. There are plugs for the TNC end, but simply bare wires on the other.

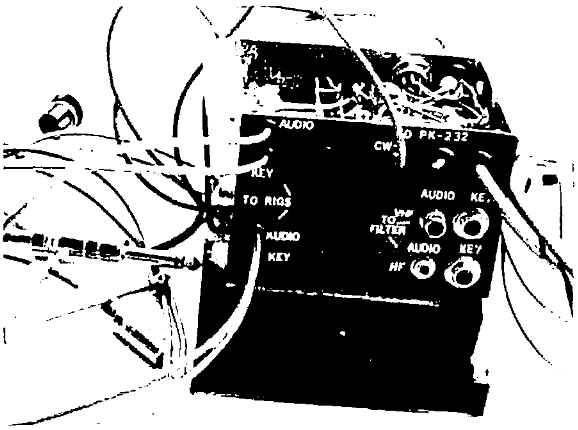
By William Schreiber, NH6N, 73-4327 Imo Street, Kailua-Kona, Hawaii 96740

PHOTO A



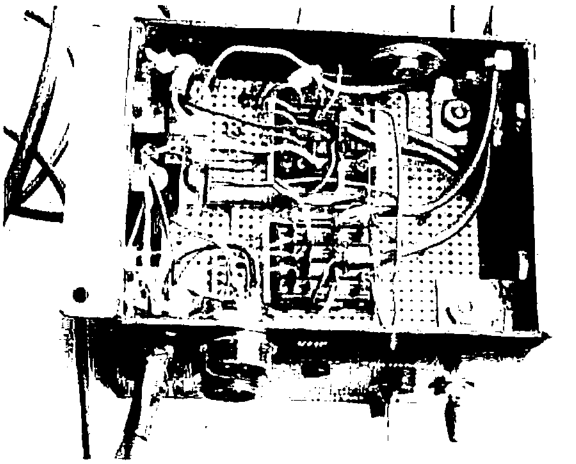
Front view—interface box.

PHOTO B



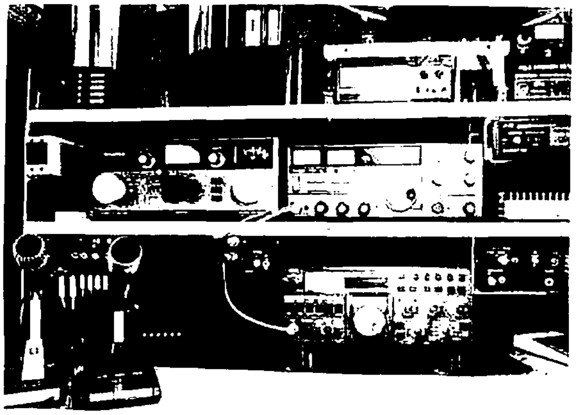
Rear view—interface box.

PHOTO C



Inside, bottom view—interface box.

PHOTO D



Interface box and rigs.

The PAKRATT, in its latest configuration, comes with a special "Communications Program" on a floppy disk. Two EPROMs inside the box allow you to boot up and use the system.

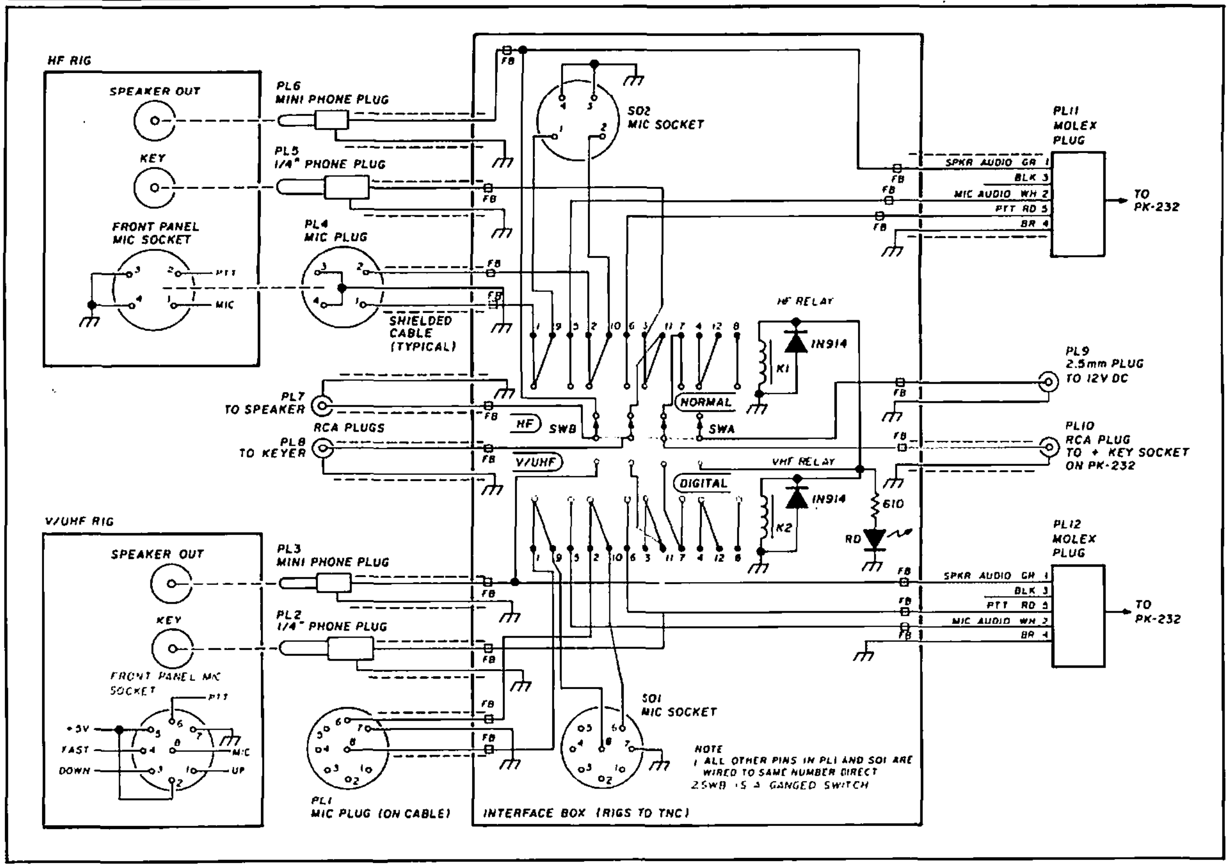
I finally had the whole thing connected and fired up the VHF rig. It worked like a charm, except when I used my Heath keyer on CW. (More on that later.) Unfortunately, the HF rig didn't work at all in any mode. After several calls to AEA, I concluded that the SSB crystal filter in my KENWOOD TS 180 was rolling off the audio at too low a frequency for the mark and space signals to reach the 232.

For several years I've been using the various ham satellites — mostly on CW where possible. But the uplink for OSCAR 10 and 13 is VHF and, as I said, I couldn't get CW out of the PAKRATT using my keyer. This TNC has a single CW output plug; I had it connected to the HF rig. Obviously, I had to do something to permit CW operation from either rig without having to disconnect cables.

A similar problem arises when the rigs are connected to the TNC in the approved manner, which involves using their microphone input plugs. If you want to shift back to normal mike usage, you have to disconnect the cables to the TNC. The idea of having to connect and disconnect cables and plugs didn't thrill me. I like things to be as convenient as possible, so I designed a simple interface box. This permits me to have everything permanently connected, and also lets me change from normal rig(s) operation to the new digital mode at the flip of a switch.

All it takes are two relays, a couple of toggle switches, and a slew of plugs and cables. The interface box ends up looking like a spaghetti factory gone wild — as you can see in the front view (**photo A**) and the rear view (**photo B**). **Photo C** shows an inside bottom view. The container was built from double-sided circuit board soldered together. Dimensions were 4″ × 2.75″ × 3″. Its

FIGURE 1



Schematic of the interface box.

PARTS LIST

Item	Reference designator	Radio Shack	All
2 each relays 4 PDT	K1, K2	275-214	RLY 124 PC
2 each socket relay	K1, K2	275-221	SRLY 4P
1 each switch SPDT	SW A	275-603	MTS-4
1 each switch 4 PDT	SW B	NA	NA *
2 each 1/4-inch phone plugs	PL 2, PL 5	274-1544	PHP 170
2 each mini phone plugs	PL 3, PL 6	274-1547	MMP
1 each 4-pin mic socket	SO 2	274-002	NA
1 each 4-pin mic plug	PL 4	274-001	NA
1 each 8-pin mic socket	SO 1	NA	NA **
1 each 8-pin mic plug	PL 1	274-025	NA
3 each RCA plug	PL 7, 8, 10	274-339	MPRP
1 each 3.5-mm plug	PL 9	274-1568	PCLID
2 each 5-pin Molex plug	PL 11, 12	NA	NA ***
10 feet 10-conductor shielded cable		NA	10 OC/522
1 each DB 25 S socket		276-1548	DB-25S
1 each DB 25 P plug		276-1547	DB-25P
2 each hoods DB25 shielded		276-1536	DB-25H
10 feet 5-conductor shielded cable		NA	5C/524
50 feet 2-conductor shielded cable		NA	2C/225
2 each 1N914 diodes		276-1520	NA
1 each LED red		276-041	LED-1
1 each LED socket		276-079	HLDCL-R
18 each ferrite beads	FB 73-2401	NA	NA ****

* Orvac Electronics, Orangethorpe Avenue, Fullerton, California
** Local Ham Store
*** Part of AEA kit supplied with PK 232
**** Amidon Associates, 12033 Otsego Street, No. Hollywood, California 91607
All Electronics, POB 567, Van Nuys, California 91408
Radiokit, Box 973H, Pelham, New Hampshire 03076

placement in regard to my rigs and assorted ancillary devices is shown in **photo D**.

Figure 1 is the schematic. *Note that I used ferrite beads on all wires entering or leaving the box.* Before I did this, all sorts of strange things took place. They were caused by RF getting into the wrong places via the interface box.

Parts for this project are available from ALL Electronics or Radio Shack. See the parts list for more information.

All things considered, it was a challenge to "go digital." But once I'd finally gotten through a string of digipeters and was connected, I had a feeling of satisfaction that I'd never encountered in my "normal" ham activities!

Note: Depending upon your radio, you may need to make some changes in the microphone connections. You can also adapt this idea for use with other TNCs. Ed.

Article B **HAM RADIO**

A TWO-LOOP 10-HZ STEP
40-70 MHZ SYNTHESIZER

By Luiz C. M. Amaral, PY1LL, Rua Dom Casmurro, 51, Jacarepagua, Rio de Janeiro, 22753, Brazil, and Carlos Alexandre C. Mathias

Achieve good image rejection without sacrificing resolution, tuning speed, locktime, and stability

Using a 40-70 MHz local oscillator is generally accepted as a means of achieving good image rejection in modern HF design. The frequency stability and accuracy of such an oscillator is achieved through synthesis. Often contradictory design requirements are high resolution, tuning speed, low noise output, spectral purity, low power consumption, small volume, and low price.[1-4] Most of the designs use many loops to obtain small step resolution. This article shows a method to overcome this difficulty.

The algorithm

Normally, unless special techniques are employed, the step size is equal to the reference source frequency. **Figure 1** shows a block diagram of such a loop. You must use a low reference frequency to provide high resolution. However, with step sizes less than 1 kHz, locking time and close-in noise are degraded. For instance, to achieve 10-Hz resolution in the 40-70 MHz range, it is usually necessary to use four or five loops.

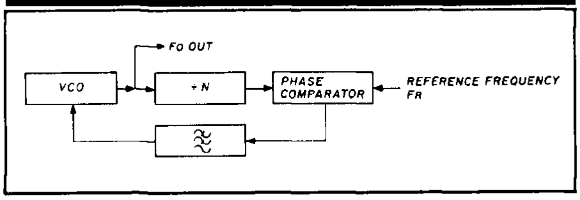
Figure 2 illustrates a two-loop block diagram that meets the combined requirements. To achieve short locking times and low noise output it is necessary to use substantially high reference frequencies — e.g., 10 kHz. If we put $Fr_1 = 9.99$ kHz and $Fr_2 = 10$ kHz in **fig. 2**, we can rewrite **eqn. 1**, $F_o = F_2 - F_1$, from **fig. 2** as:

$$F_o = (M \times 10 - N \times 9.99)\ \text{kHz} = [10 \times M - (10 - 0.01) \times N]\ \text{kHz} = [10 \times (M - N) + 0.01 \times N]\ \text{kHz} \qquad (2)$$

where N and M are as defined in **eqn. 1**

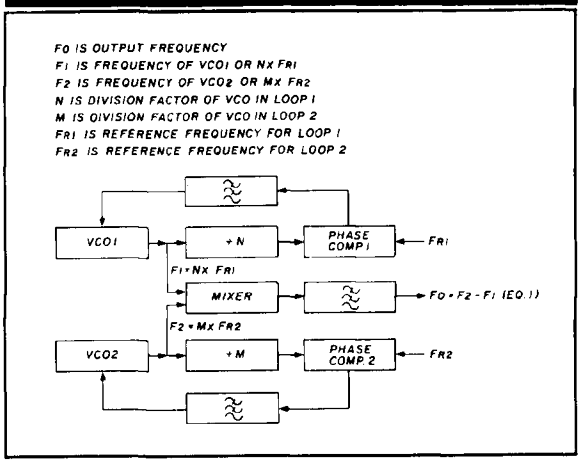
To make 10, 100, or 1,000-kHz steps (or their multiples), change only the divider, M. For steps of 10, 100, or 1,000

FIGURE 1



Loop diagram for simple one-loop synthesizer.

FIGURE 2



Algorithm for present synthesizer.

Hz (or their multiples), you have to change the values of N amd M to maintain M − N unchanged.

For instance, if you need a step 30 Hz up, increase N by 3 ($3 \times 0.01 = 30$ Hz) and M by 3. So,

$F_{initial} = [10 \times (M - N) + 0.01 \times N]$ kHz

$F_{finai} = [10 \times (M + 3 - (N + 3)) + 0.01 \times (N + 3)]$ kHz

Step $= F_{initial} - F_{final} = 0.03$ kHz $= 30$ Hz

Derivation of design equations

One of the problems of 40-70 MHz synthesis using one loop is the rather high relative range: 30 MHz in a 40-MHz VCO. One of the advantages of the present method is that you can use two VCOs in a higher VHF band, making the relative range a minor problem. (In our units we have used F1 at 160-200 MHz and F2 at 120-130 MHz, both single loops.)

Now let's derive the design equations for these arrangements. Remembering that the output frequency is a seven-digit decimal number (e.g., 47,936.42 kHz), put:

$F_o = 10{,}000 \times A6 + 1{,}000 \times A5 + 100 \times A4 + 10 \times A3 + A2 + 0.1 \times A1 + 0.01 \times A0$ (in kHz).

Similarly the division factors N and M may be written, as they are integers:

(F_1 and $F_2 < 1{,}000$ MHz, so $Mi = Ni = 0$ for $i > 4$).

$N = N0 + 10 \times N1 + 100 \times N2 + 1{,}000 \times N3 + 10{,}000 \times N4$

$M = M0 + 10 \times M1 + 100 \times M2 + 1{,}000 \times M3 + 10{,}000 \times M4$

Using **eqn. 2** you have:

$10{,}000 \times A6 + 1{,}000 \times A5 + 100 \times A4 + 10 \times A3 + A2 + 0.1 \times A1 + 0.01 \times A0 = 10 \times [M0 - N0 + 10 \times (M1 - N1) + 100 \times (M2 - N2) + 1{,}000 \times (M3 - N3) + 10{,}000 \times (M4 - N4)] + 0.01 \times (N0 + 10 \times N1 + 100 \times N2 + 1{,}000 \times N3 + 10{,}000 \times N4)$

Equating the corresponding terms you have:

a) $M4 - N4 = 0$
b) $M3 - N3 = A6$
c) $M2 - N2 = A5$
d) $M1 - N1 + N4 = A4$
e) $M0 - N0 + N3 = A3$
f) $N2 = A2$ **(3)**
g) $N1 = A1$
h) $N0 = A0$

Because the Ai are given numbers, you have eight equations with ten unknowns to determine Ni and Mi. This gives you two degrees of freedom to locate the ranges of F_1 and F_2. (You must establish values for two parameters, so choose N4 at first.) If the values you choose for N4 (and M4) are too high, the dividers (which can be preset) may fail to operate and the noise performance will be poor because of the great division factor. But if N4 is too small, you'll have problems with the relative range of the VCO. In the present case, a good choice will be 1 for N4 (and M4).

The range of F_1 (N loop) is $\approx$ 10 MHz because, to cover 9.99 kHz (the maximum step not covered by the M loop alone) in steps of 10 Hz, we have 1,000 channels with 9.99 kHz of reference frequency, which gives 10 MHz. So, the F_2 (M loop) range is 10 MHz + 30 MHz (range of the output) = 40 MHz.

The other degree of freedom permits you to fix the value of N3. Choose 2 for this (meaning that with N4 = 1, for $\approx$ 10-MHz range, we have F_1 ranging from 120 to 130 MHz, and, consequently, F_2 ranges from $\approx (120 + 40) = 160$ to $\approx (130 + 70) = 200$ MHz. These frequencies are convenient enough for the dividers and relative ranges of the VCOs.

Now rewrite the expressions of N and M using **eqn. 3** and the chosen values for N3, N4, and M4:

$N = 10{,}000 \times N4 + 1{,}000 \times N3 + 100 \times N2 + 10 \times N1 + N0$ or,

$N = 12{,}000 + 100 \times A2 + 10 \times A1 + A0$ **(4)**

$M = 10{,}000 \times M4 + 1{,}000 \times M3 + 100 \times M2 + 10 \times M1 + M0 = 10{,}000 + 100 \times (A6 + 2) + 100 \times (A5 + A2) + 10 \times (A4 - 1 + A1) + (A3 - 2 + A0)$ or,

$M = 11{,}988 + 1{,}000 \times A6 + 100 \times (A5 + A2) + 10 \times (A4 + A1) + (A3 + A0)$ **(5)**

As the output ranges from 40,000.00 to 69,999.99 kHz, the value of A6 may be 4, 5, or 6. A5, A4, A3, A2, A1, and A0 may be 0 to 9. Now it's possible to calculate the exact ranges of N, M, F_1, and F_2:

a. Minimum N: $A2 = A1 = A0 = 0$.

From **eqn. 4**: $N_{min} = 12{,}000$.

b. Minimum F_1: **(fig. 2)** $F1_{min} = 9.99 \times N_{min} = 119{,}880$ kHz.

c. Maximum N: $A2 = A1 = A0 = 9$.

From **eqn. 4**: $N_{max} = 12{,}999$.

d. Maximum F_1: **(fig. 2)** $F1_{max} = 9.99 \times N_{max} = 129{,}860.01$ kHz.

e. Minimum M: $A6 = 4$; $A5 = A4 = A3 = A2 = A1 = A0 = 0$.

From **eqn. 5**: $M_{min} = 15{,}988$.

f. Minimum F_2: **(fig. 2)** $F2_{min} = 10 \times M_{min} = 159{,}880$ kHz.

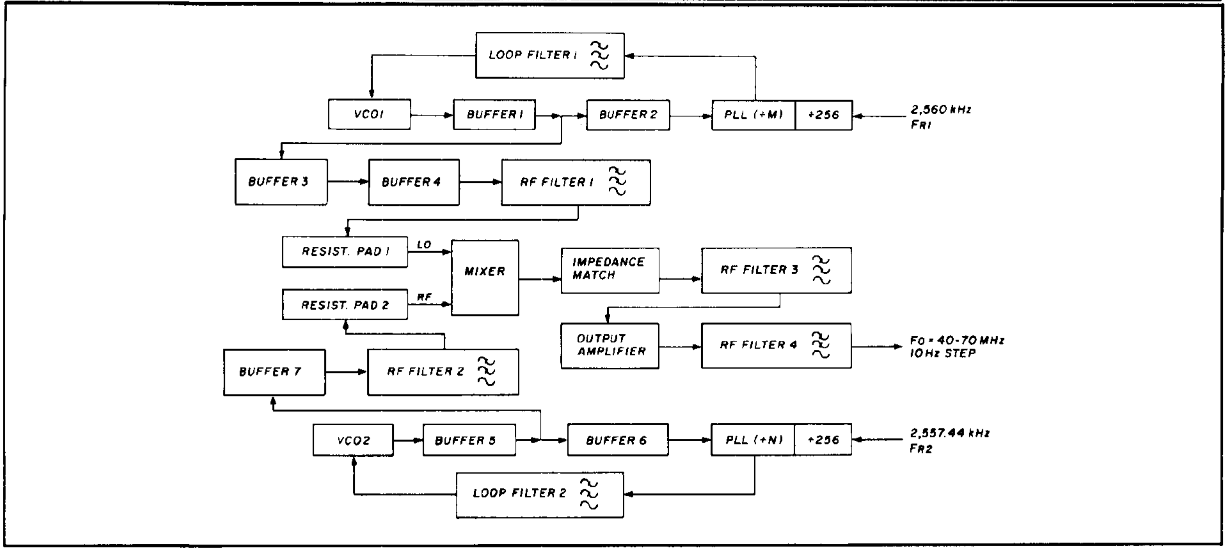
g. Maximum M: $A6 = 6$; $A5 = A4 = A3 = A2 = A1 = A0 = 9$.

From **eqn. 5**: $M_{max} = 19{,}986$.

h. Maximum F_2: $F2_{max} = 10 \times M_{max} = 199{,}860$ kHz.

For example, suppose that you want to synthesize an output of 56,721.98 kHz. Then A6 = 5, A5 = 6, A4 = 7, A3 = 2, A2 = 1, A1 = 9 and A0 = 8.

FIGURE 3



Block diagram for the present synthesizer.

Using **eqns.** 4 and 5 you have:
$N = 12{,}000 + (100 \times 1) + (10 \times 9) + 8$ or, $N = 12{,}198$ and
$M = 11{,}988 + (1{,}000 \times 5) + (100 \times (6 + 1)) + (10 \times (7 + 9)) + (2 + 8)$ or,
$M = 17{,}858$
So, $F_1 = 9.99 \times 12{,}198 = 121{,}858.02$ kHz and $F_2 = 10 \times 17{,}858 = 178{,}580$ kHz.
It works because $F_o = F_2 - F_1 = 56{,}721.98$ kHz.

The algorithm shows that this is a type of synthesis which is convenient to implement with microprocessor control. The calculations become even more involved when two-modulus prescalers are used within the loops.

The complete design

Our particular assembled unit has been built according to the block diagram in **fig.** 3. The PLL blocks each include one two-modulus prescaler. We used MC-12016[5], 40/41 type); we have built them with MC-145156[6] PLLs. However, if you use the MC-145158, the reference frequency problem may be easier to solve by entering only one reference in both loops (e.g. 9,990 MHz — and programming the reference dividers with 999 for the M loop and 1,000 for the N loop). We've used the PD phase detector output (from the phase comparator of the PLL) to avoid operational amplifiers in the control lines. The resulting reference rejection has been better than 60 dB down.

Now let's analyze each block of fig. **3**:

a. VCO 1 and 2: Because their frequencies fall in the VHF range, the low noise J-FET, like the U-310 (or the plastic J-310 family), is a convenient transistor choice.[7,9] If you don't plan to pretune, take care in your layout and choice of components to permit VCO 1 to cover its 40-MHz range.

b. Buffers 1, 2, 3, 6, and 7 may employ bipolar transistors like the BFY-90 for low noise, high isolation, and broadband operation. Buffer 5 may be a dual-gate MOS-FET — try the MFE-521 or 3N-211[7]. For buffer 4 use a high output level broadband linear transistor (a BFW-16A) to get a suitable signal power for the mixer LO input.

c. We chose an SRA-1 bridge diode double-balanced mixer from Mini Circuits to get a very low spurious response. This is very dificult to obtain using other types of mixing devices. For this purpose we've had to "clean" both LO and RF port signals concerning harmonic content with RF filters 1 and 2. Two resistor pads have been used to couple both signals to the mixer under correct resistive impedance (50 Ω).

d. A BFY-90 stage presents the correct resistive load to the mixer (50 Ω). Its output passes a third RF filter to block the harmonic power (now generated by the mixer itself) and drives the final (BFW-16A) amplifier stage through another BFY-90 stage. This gives a high-level power ($\approx$ 12 dBm) to the first mixer of the receiver. RF filter number 4 maintains the output free from harmonics.

Final comments

This article presents an algorithm rather than a circuit design. The synthesizer itself may be built using all the standard techniques for low noise operation, like in-loop mixing for lowering the division factors, low noise phase comparators (HEF-4750[8] series from MULLARD), and pretuned systems to get quieter varactor control. All these techniques are fully described in the literature[2,3] so we won't discuss them here. The only point we'd like

to emphasize is that the higher the division factors, the poorer the close-in noise, because the noise from reference is multiplied by a greater number and we have a worse signal-to-noise ratio at the phase comparator. So, without in-loop mixing (or another equivalent technique to diminish N and M), special care must be taken with crystals and crystal oscillators to minimize in-band noise.[9]

Concerning stability and accuracy, note that 10 Hz in 200 MHz means 0.05 ppm, so that the use of simple "non-mastered" reference sources doesn't seem to make sense.

Conclusions

We've presented a method to synthesize three million 10-Hz channels (40-70 MHz) with a reference-to-step ratio of 1,000 by using only two loops. We have used the frequency difference between the two loops, but the sum may be used in the same manner as long as you take care that the spurious and harmonic signals don't fall within the output band region.

References

1. Ulrich L. Rohde, DJ2LR/KA2WEU, *Digital PLL Frequency Synthesizers-Theory and Design*, Prentice Hall.
2. V. Manassevitch, *Frequency Synthesizers-Theory and Design*, John Wiley & Sons.
3. W.C. Lindsey and M.K. Simon, *Phase-locked Loops and Their Application*, IEEE Press.
4. W.F. Egan, *Frequency Synthesis by Phase Lock*, John Wiley & Sons.
5. Motorola MECL Data Book, Series C, Motorola, Inc. 1982.
6. Motorola CMOS/NMOS Special Functions Data, Series A, Motorola Inc., 1984, pages 6-95 to 6-119.
7. Motorola RF Data Manual, Motorola Inc., 1980.
8. Philips, *Digital Integrated Circuits-LOCMOS HE4000B Family*, N.V. Philips Gloeilampenfabrieken, 1980.
9. W. P. Robins, *Phase Noise in Signal Sources (Theory and Application)*, IEEE Telecommunications Series 9.

Article C HAM RADIO

NOVEMBER WINNERS

Congratulations to Alan Unangst, WC7R, our November sweeps winner and L.B. Cebik, W4RNL, author of November's most popular WEEKENDER – "Improving Operation with the MFJ 989 Transmatch." Both will receive a handheld radio. To enter for January's drawing, send in the evaluation card bound into this issue, or submit a WEEKENDER project. You could be our next winner! *Ed.*

Correct address

The address given for Hal Silverman, W3HWC, in the October 1988 issue (page 63) is incorrect. If you wish to contact Hal, his current address is: 14004 Harrisville Road, Mt. Airy, Maryland 21771.

THE HAM NOTEBOOK

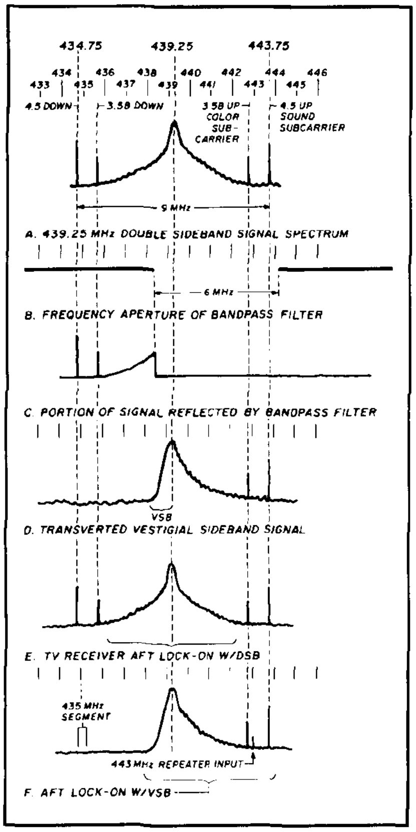
Clean ATV the modern way

Why do **Amateur** TV signals cause interference, while the interference from million-watt commercial TV stations is insignificant? Commerical TV stations use highly efficient transmitting systems, because any interference would be devastating to many other services and expensive in terms of power wasted. Most hams use the double-sideband method shown in the spectrum of **fig. 1A**. This method conforms to the lastest trend of using a small self-contained package, with few "bells and whistles".

In the past, ATV enthusiasts would heap together a mixture of homebrew and surplus equipment from TV stations. Their shacks looked as if 747s had crashed into them — twice. That was enough to keep many of us from getting involved. Today with VCRs, cameras, and computers in almost every home (and TV sets in half the rooms), you don't need to add much to receive and transmit state-of-the-art signals.

Modulators that generate a vestigial sideband signal (VSB) at low VHF frequencies are readily available and inexpensive.[1] The output has the color and sound sidebands "locked in" at a low RF level. When transverted upward to UHF, the lower sidebands are inserted again by way of the mixing process. This signal is still below 1 watt and can now be filtered, using helical resonators,[2] for the final cleanup. Compare

FIGURE 1



Simplified television spectra.

fig. 1A with **fig. 1D**. When a filter is used to remove the lower sideband of a high-power UHF signal, both insertion loss and losses from SWR can be quite high. That, coupled with the additional connector losses, can cause undue strain on the final amplifiers. The most obvious benefit of the VSB method is that the AFT in the average TV set locks on. Sound and color also lock in on strong or weak signals.

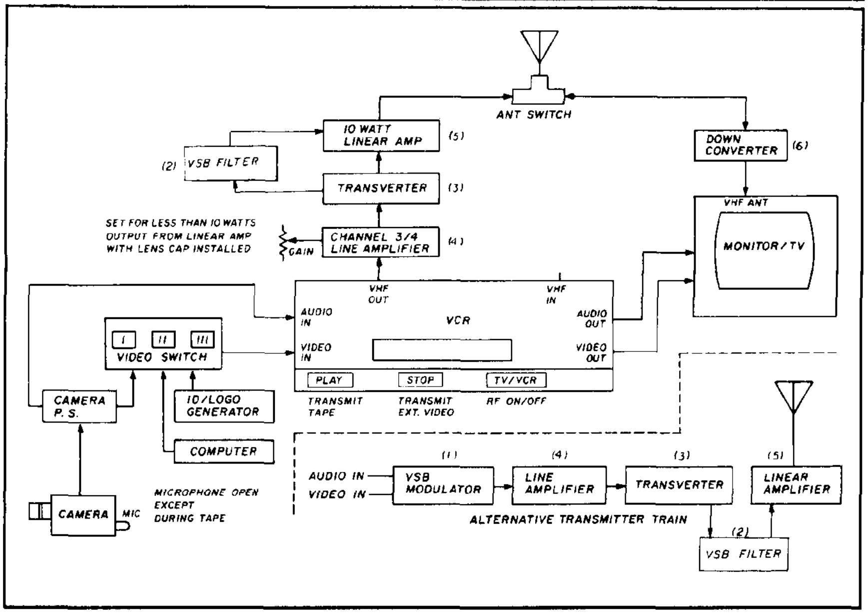
With a double-sideband signal (unless it's quite strong), you must tune out the picture to hear the sound. **Figures 1E** and **1F** show brackets whose width represents the 6-MHz ideal bandwidth of a TV set, and how the AFT will (essentially) center on the energy of the signal. Real sets are much narrower. **Figure 1F** also shows the 435-MHz satellite segment that may suffer interference from a 439.25-MHz double-sideband signal. This information is extremely important if you choose 421.25 MHz for the carrier; there is danger of transmitting out of the band.

A VCR has a modulator that transmits a fairly good VSB signal. The output can be the channel 3 or 4 *signal* required by the transverter.[3] The VCR makes a perfect control point for your ATV station. Although the operating format varies from model to model, all operations are accessible on the VCR. A separate video selector switch that feeds the VCR's VIDEO-in jack can connect any desired source. Many transverters and amplifiers idle with little current drain when excitation is removed; this simplifies transmitter switching. However, you must switch your antenna separately.

Figure 2 shows a comprehensive ATV station using a transverted VSB signal. I've also shown an alternative transmitting system that uses only a modulator. But, try using a VCR if you have one; it's a valuable video source. The VHF amplifier brings the 0.3-μW (5 mV) VCR output signal up to the 1 mW level required by the transverter. You can use a channel amplifier (for feeding apartment houses), or one or more of the multiset driver units called rabbits.[4]

Some of the control buttons are shown at the bottom of the VCR block. The names appearing on the

FIGURE 2



A comprehensive ATV station using a transverted VSB signal.

front of the VCR are inside the block. The actual functions, as they relate to ATV system operation, are listed below the block. The format for my unit, a Toshiba, allows VHF excitation control from the VHF-out jack using the TV/ VCR or PLAY switch. In VCR mode (indicator lit), the internal modulator is energized and fed video from a tape — or whatever is fed to the VIDEO-in jack. A running tape overrides external video until you push the stop button.

To stop transmitting, push the TV/VCR switch again. The indicator light will go out. In this mode, a sufficiently strong signal from a downconverter entering the VHF-in jack, could pass throuh the VCR, and excite the transverter. When used in this way, with proper filtering, the VCR can become a repeater — but it requires two antennas. To be more specific, VHF-out follows VHF-in when in TV mode, and follows tape (or VIDEO-in) in VCR mode. However, VIDEO-out follows a tape if one is running; if a tape isn't playing, it follows VIDEO-in.

I've used a Hamtronics transverter for both 432-MHz sideband and ATV. It worked well in both situations, but I had some difficulty with the tune-up. Then I found a note that recommended tuning the UHF amplifier section with an accurate signal generator fed in through the coupling capacitor at the mixer output. Do this before tuning the local oscillator train to prevent mistaking the wrong output from the mixer — or the local oscillator frequency itself — for the desired one. If you don't have access to a reliable signal generator, order a completely wired and aligned board. If a high-power channel 3 or 4 station is close by, opt for a crystal on the channel that you don't have in your area. This will minimize interference. Also, don't mistake oscillations in the VHF line amplifier for trouble in the transverter.

With the great wealth of video devices available today, there's no lack of interesting material to transmit. Keep family home movies to a minimum and remember that copyrighted tapes are taboo. There are many interesting events, in Amateur Radio and other hobbies, to tape and present. Of course, there are so few of us skilled in the art of presentation that it would be rare to find a tape warranting over five minutes of air time. Though NASA and USWS material is (in a way) owned by the public, you usually need to contact them for a letter of authorization. Music is still illegal in Amateur Radio transmissions and should be edited out of any tapes you show.

References

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2. Spectrum International Inc., Models PSF 421, PSF 434, PSF 439.
3. Transverter, Hamtronics XV-4, XTAL for channel 3 (61.25) input standard. Request Channel 4 (67.25) XTAL if needed.
4. Single channel VHF amplifier, Jerrold SMA-(*), (* Channel number) can be sweep-tuned for any low VHF channel.
5. P.C. Electronics PA-5, 10-watt power module.
6. P.C. Electronics TV-2G, TV-4G, Wyman Research DC-1, Communication Concepts ATV-2, ATV-3.

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Article D **HAM RADIO**

COLLECTOR MATCHING NETWORKS

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Tips for designing matching networks

For many, access to Computer Aided Design (CAD) software packages has rekindled interest in designing matching networks and filters for specific applications. Some years ago, I was involved in comparing the frequency response — bandwidth and stopband attenuation — of collector matching networks commonly used in bipolar transistor PAs. For the single HF bands, a lot of Amateur designers choose a narrowband common-emitter amplifier which couples RF through matching networks at the input and output of the active device; it's still the favorite for VHF.

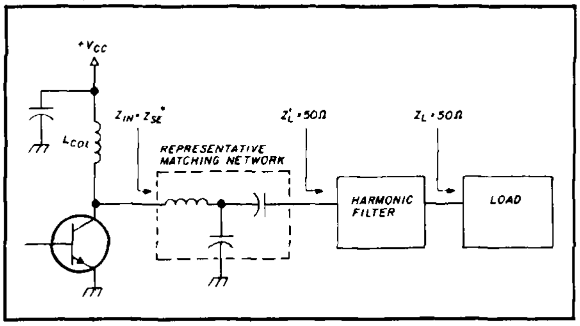
Power and attentuation

One way to find the response of a matching network is to compute the input impedance Z_{in} of the network (or network-harmonic filter combination) at regular (or logarithmically spaced) frequency steps. Many CAD programs (including mine) simplify the matching network step by step to the simplest series-equivalent circuit (R_{in} and X_{in} in series) and evaluate $Z_{in} = R_{in} + jX_{in}$. This sort of analysis (known as network reduction) is tedious when done by hand, but is well suited to a computer. Using Z_{in}, calculate the current flowing into the network which leads to the response and the relative power dissipated in the load. This approach doesn't require a lot of computer memory and is suitable for small programmable calculators. Several years ago I wrote programs for a TI 58; it still handles my matching network calculations.[1]

In the following algorithm, the relative power P_L drawn by the load of a PA is

$$P_L(dB) = P_T + IL \qquad \text{(1A)}$$

FIGURE 1



Partial circuit of an amplifier showing output circuit impedances at the operating frequency.

$$P_T(dB) = 10 \log \frac{4R_{se}R_{in}}{(R_{se} + R_{in})^2 + (X_{se} + X_{in})^2} \qquad \text{(1B)}$$

Where P_T is the relative power output of the PA (drawn at the network input) and IL is the dissipative insertion loss of the network (or network-harmonic filter combination). Since IL is negative, P_L is less than P_T by the amount of dissipative loss. The series-equivalent collector output impedance is $Z_{se} = R_{se} + jX_{se}$ and $Z_{in} = R_{in} + jX_{in}$ is the series-equivalent input impedance of the collector matching network. The impedance relationships are shown in **fig. 1**. Maximum output power (0 dB relative power) is drawn when $Z_{in} = Z^*_{se}$, the complex conjugate of the collector output impedance. The bandwidth of the amplifier is defined as the frequency interval for which the relative power holds within −1 dB of maximum. Many designers consider −1 dB a practical limit for the power curve. This limit corresponds to a return loss at the collector of −8.0 dB or a VSWR of 2.32.

A number of CAD programs include the IL of the net-

work or filter, some at a considerable level of sophistication.[2] Below 30 MHz, you can approximate IL by placing the loss resistances R_{loss} in series with the inductors. (Capacitor losses can generally be neglected at HF.) Then $R_{loss} = X_L/Q_u$, where X_L is the inductive reactance and Q_u is the unloaded Q of the coil.

The collector output resistance R_{se} is a large-signal parameter. Use the DC collector voltage and the desired output power for calculations below 30 MHz.[3] Many PA transistor manufacturers supply data for both R_{se} and X_{se} (often in parallel-equivalent form). R_{se} is small in high-power transistors (usually less than 5 ohms), and X_{se} is usually capacitive below 100 MHz.

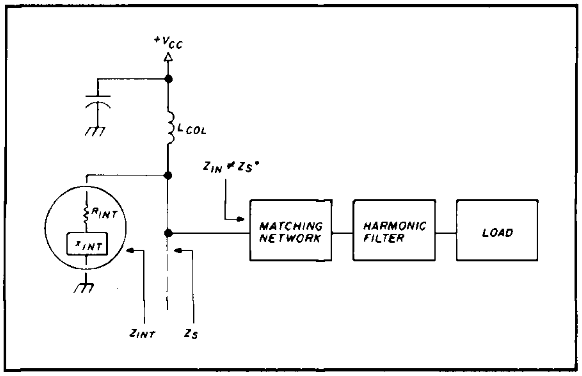
The computer program used for power output also lends itself to the analysis of the stopband attenuation of the collector matching network (or network-harmonic filter combination). The attenuation at the load is A_L(dB) $= A_m + IL$, where A_m (the mismatch attenuation) is computed with an equation of the same form as eqn. 1B, with the source impedance Z_s replacing Z_{se}. $Z_s = R_s + jX_s$ is made up of the internal impedance of the transistor in parallel with the bypassed collector choke, as shown in **fig. 2**. The internal resistance R_{int} is largely a function of operating parameters, although transistor characteristics play a role. As the operating conditions become increasingly nonlinear, the transistor operates more in a saturated condition (maximum possible collector current). As a result, collector current is drawn at lower average collector voltages and R_{int}, by Ohm's law, drops lower. R_{int} is several kilohms or higher in the unsaturated, linear classes (A and AB), a few hundred ohms in class C, and a few ohms or less in the saturated, switching classes (D and E).

For maximum output power, the collector matching network is designed to transform the load impedance Z_L to the conjugate of the collector output impedance Z_{se}^* rather than the true source impedance Z_s^*. Consequently, the collector matching network has a mismatched input because it really sees Z_s. In network/filter vernacular, the network (and harmonic filter if used) are single terminated. A mismatched input usually causes the frequency response of the network (or network-filter combination) to differ substantially from the ideal response with both ends terminated.

Matching network Q

For a 3 (or more)-element network, you can specify the desired network Q or relative half-power bandwidth. The Q is usually determined by a parameter called the design or loaded Q (Q_L). For narrowband transistor PAs the Q_L of the output network is generally 4 to 6. Many Amateur designers confuse Q_L with the circuit Q or operating Q (Q_{op}) of the network — the Q which the network exhibits in an actual circuit. Q_{op} reflects the loading on both ends of the matching network, whereas Q_L is fixed by the loading on only one end.[4] Determine the

FIGURE 2



Representation of a common-emitter PA to illustrate the source impedance.

operating Q by dividing the frequency for which the network is tuned by the calculated (or measured) −3 dB bandwidth of the network.

Besides the Q, the 4-element collector matching network adds the shape of the passband. For example, if your goal is a PA with a large bandwidth (perhaps for 2-band coverage), you can tailor a 4 (or more)-element network for a Butterworth (maximally flat) or a Chebyshev response with a 1-dB passband ripple. I'll show how it's done later.

The amplifier

To determine bandwidth and stopband attenuation, you need to "design" an amplifier which will yield realistic numbers for the collector output impedance Z_{se} and the source impedance Z_s. The amplifier I chose operates class AB and uses a Motorola MRF422 transistor rated at 150-watts PEP output to 30 MHz; it loafs at 75-watts PEP at 7 MHz in this PA.

Estimate the collector output impedance using the graphs on the MRF422 data sheet.[5] You'll need the output resistance R_{out} versus frequency and the output capacitance C_{out} versus frequency. The data are in parallel-equivalent form for 150-watts PEP. At half the rated power, R_{out} about doubles and C_{out} drops from 4200 pF to an estimated 2600 pF at 7 MHz.[6] R_{out} is scaled by a factor of ×2 and C_{out} by 2600/4200 or ×0.619. Fortunately, these factors are nearly independent of frequency. For power calculations, C_{out} is converted to X_{out} by $X_{out} = -1/2\pi fC_{out}$, and the parallel-equivalent output impedance $Z_{out} = R_{out} + jX_{out}$ is transformed to the series-equivalent output impedance $Z_{se} = R_{se} + jX_{se}$. This is done by first inverting R_{out} and X_{out} to give the conductance G_{out} and the susceptance B_{out} ($B_{out} = -1/X_{out}$. Note the sign change). Then $Y_{out} = G_{out} + jB_{out}$ is inverted to give $Z_{se} = 1/Y_{out}$. W7DHD has a BASIC routine which performs the complex inversion by dividing Y_{out} into 1 + j0.[7] Z_{se} = 4.66 −j4.18 ohms for 75-watt MRF422 PA at 7 MHz, including the contri-

bution of the 3-μH collector choke (which causes a 6.6 percent increase in R_{se}). I know a 3-μH collector choke for a 7-MHz PA may raise a few eyebrows, but I chose a low inductance to avoid low-freqency resonances with output network capacitance which can lead to instability.[8] The choke reactance, over 130 ohms at 7 MHz, doesn't cut into the output power significantly. With Z_{se} (and Z_{in}) calculated at regular frequency steps above and below the frequency for which the PA is tuned, you can use eqn. **1** to compute a power curve and -1 dB bandwidth.

To determine the stopband response, you'll need a simple, tractable model to calculate the source impedance Z_S. As I mentioned, the internal collector resistance R_{int} in an AB class PA is in the kilohm range. In fact, R_{int} is so much higher than the collector choke resistance that R_{int} can be considered invisible. This leaves the bypassed collector choke as the source impedance (see **fig. 3**). That is, $Z_s = Z_{col} = R_{col} + jX_{col}$, where the series-equivalent loss resistance of the choke is $R_{col} = X_{col}/Q_u$. With the 3μH, $Q_u = 100$ collector choke, the choke impedance at 7 MHz is $Z_{col} = 1.319 + j131.9$ ohms, because $X_{col} = 2\pi fL_{col}$ and $R_{col} = X_{col}/Q_u$. Since R_{col} and X_{col} are directly proportional to the frequency, the impedance can be easily scaled to any frequency. For example, R_{col} and X_{col} at the second harmonic are just twice their values at 7 MHz. Now determine the stopband response with Z_s in place of Z_{se} in eqn. **1**, just as you determined the power curve.

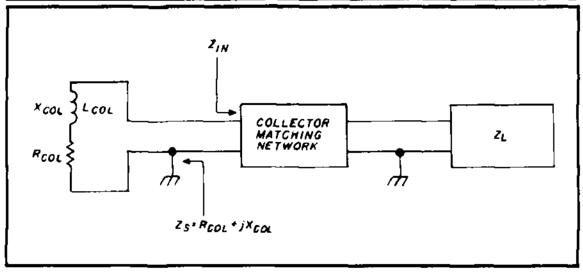
Designing the matching networks

The low-pass collector matching networks designed for the MRF422 PA are shown in **figs. 4A** through **4E**. (The capacitive voltage divider, **fig. 4D**, actually has a pseudo-bandpass response.) These networks transform the 50-ohm load impedance to $Z_{in} = 4.66 + j4.18$ ohms at 7 MHz. The 3-element networks come from formulas in Hayward and DeMaw's *Solid State Design*[9] and the *ARRL Handbook*.[10] These formulas assume a pure (non-reactive) input resistance, and lossless coils and capacitors. First, component values are calculated giving $R_{in} = 4.66$ ohms at 7 MHz with a 50-ohm resistive load and a loaded Q of 4. Next, the network input reactance is adjusted to $+j4.18$ ohms to compensate for the output reactance of the active device, $X_{se} = -j4.18$ ohms. The adjustment involves adding 4.18 ohms to the calculated reactance of the series inductances in **fig. 4A** through **4C**. The capacitive voltage divider (CVD, **fig. 4D**) has a shunt input capacitor. Here it's easier to use the parallel-equivalent output capacitance (2426 pF for the MRF422 with the effect of L_{col} included) and subtract 2426 pF from the calculated value of the shunt input capacitor at 7 MHz.

If you're not interested in insertion loss, you're finished with the 3-element designs. To observe the effect of imperfect coils (as I did), you need to input the unloaded Q of the coil(s) and the other network parameters into the analysis program. I used coils with a Q_u of 175 for the networks in **fig. 4**. Imperfect coils will throw off the design Z_{in}. I use a repetitive procedure of systematically adjusting element reactances and recomputing input impedance until I obtain the desired Z_{in} again. Don't change the input series coil or shunt capacitor — the elements you already modified for collector output reactance. These elements are also determined by the chosen Q_L of the network. Changing the remaining two elements will always regenerate the desired Z_{in}.

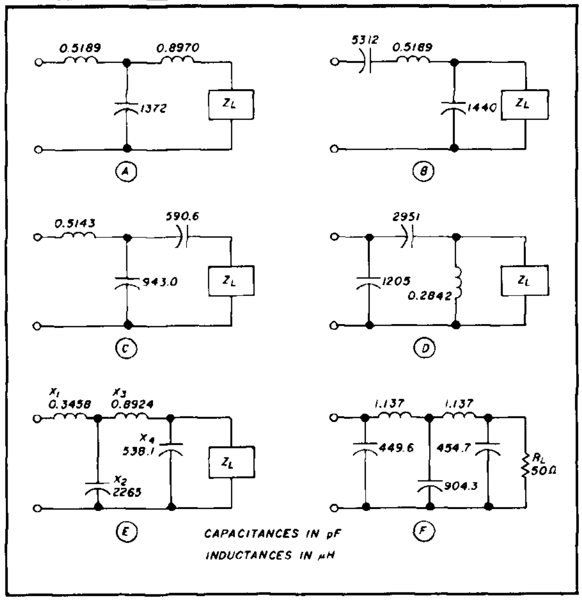
You need to take a different tack when designing the 4-element tandem-L network (TL, **fig. 4E**). There aren't

FIGURE 3



Equivalent circuit of the source impedance Z_s seen by the collector matching network of a class AB common-emitter amplifier.
$X_{col} = 2\pi fL_{col}$, L_{col} is the collector choke. $R_{col} = X_{col}/Q_u$.

FIGURE 4



Collector matching networks. (A) symmetrical T (LCL), (B) controlled-Q L (CQL), (C) unsymmetrical T (LCC), (D) capacitive voltage divider (CVD), (E) tandem L (TL). Element values are to match a 50 ohm load to the MRF422 collector load impedance, 4.66−j4.18 ohms at 7 MHz. Design Q is 4 for the 3-element networks, 3.56 for the TL. (F) A half wave low-pass filter (HWF). Q_u = 175 for all coils.

any simple, exact formulas which allow you to independently choose the bandpass shape and the design Q. Fortunately you can calculate the end elements X_1 and X_4 for any desired bandpass and Q, and this leads to preliminary values for the inner elements X_2 and X_3.

The TL network in **fig. 4E** was designed for an optimally flat (Butterworth) response with a constant voltage (zero output resistance) source — a reasonable approximation for a transistor with an output resistance of a few ohms, like the MRF422. If the input-end Q of the TL is defined as $Q_{in} = X_1/R_{in}$ and the load-end Q is $Q_{load} = R_L/X_4$, the parameter indexing a maximally flat response is $Q_{in}/Q_{load} = 2$.[11] The design Q for this network is $Q_{in} + Q_{load} = 3.55$. These two conditions are solved for Q_{in} and Q_{load}, from which X_1 and X_4 are calculated. A ratio Q_{in}/Q_{load} between 1 and 2 gives a broader hammock-shaped response, if some passband ripple is allowable. For TL networks with a Q_{in}/Q_{load} of 2 or less, $X_2 \simeq -X_1$ and $X_3 \simeq -X_4$. (Watch the signs!) Now add 4.18 ohms to X_1 to compensate for the MRF422 output capacitance, and compute the input impedance with the preceding network elements. Systematically adjust X_2 and X_3 to steer Z_{in} to the design value, 4.66 + j4.18 ohms for the MRF422.

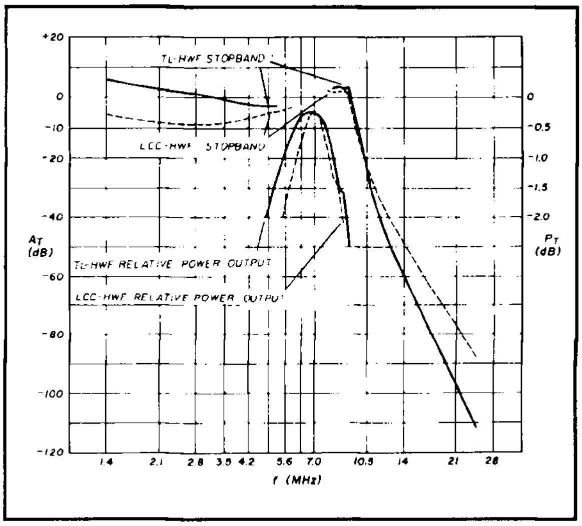
Figure 4F shows a half-wave harmonic filter which yields $Z_{in} = Z_{load} = 50 + j0$ ohms at 7 MHz and reduces harmonics 20 dB or more. The name half wave is derived from the impedance characteristics of the filter.[12] Like a half wavelength of transmission line, the half-wave filter reproduces at its input (with a 180-degree phase delay) whatever load impedance is coupled into it at the design frequency.

Frequency response curves

Both the relative power output of the PA and the stopband attenuation of the output circuits are referenced to 0 dB at the frequency for which the PA is tuned, and plotted versus frequency on the same graph. This combined power and attenuation curve (which I call a composite response curve) yields information at a glance on the width and shape of the power curve (assuming constant drive level and device gain), and harmonic rejection.

Figure 5 illustrates two composite response curves for the MRF422 PA. One is for a 3-element matching network (LCC, **fig. 4C**) and the other for the 4-element TL network of **fig. 4E**. Both matching networks are tied to the half-wave harmonic filter. These curves show clearly the large increase in harmonic attenuation when going from the low to the high-frequency edge of the 0, −1 dB power curve. For example, in the LCC-HWF response, the second harmonic attenuation A_2 corresponding to the low-frequency edge at 6.15 MHz, is only −40 dB (at 12.3 MHz). A_2 corresponding to the high-frequency edge at 7.9 MHz is 18 dB greater at −58 dB. Allowing for a second harmonic level of −12 dB in the amplifier

FIGURE 5



Composite response curves for TL-HWF and LCC-HWF PA output network-harmonic filter combinations. Amplifier is a 75-watt class AB MRF422 tuned for 7 MHz. Expanded P_T scale for relative power output is at right.

itself,[6] these A_2s reflect harmonic outputs of −52 dB and −70 dB. Although −52 dB is within FCC regulations, from my experience with interference I consider −60 dB the maximum harmonic output from a 75-watt or larger PA that assures peace with neighbors and nearby Amateurs. So, the net harmonic rejection of the output circuits should be −60 dB − (−12 dB) = −48 dB. This rejection specification moves the lower frequency limit for the PA with an LCC-HWF output circuit from 6.15 to 6.9 MHz, defining an operating range of 6.9 to 7.9 MHz.

According to the −48 dB criterion, the operating range of the MRF422 PA with a TL-HWF circuit is 6.2 to 8.1 MHz. The relative width of this range is 27 percent — sufficient to cover the whole 75/80-meter band, or to bridge two adjacent bands between 14 and 30 MHz. (We're assuming that the response doesn't change drastically when the amplifier is tuned for a different frequency — an assumption I have found to be generally true.) With the TL-HWF combination, the power curve is at least 37 percent wider, while the harmonic rejection is several dB better than with the 3-component networks.

The main features of all of the composite responses are summarized in **table 1**. The −1 dB bandwidth decreases as the operating Q increases, while the insertion loss and harmonic attenuation increase. If Q_{op} instead of Q_L is fixed for the various 3-component networks, the apparent differences in bandwidth and filtering ability practically vanish. For example, in addition to the CQL, the LCL, LCC, and CVD matching networks with $Q_{op} = 4.9$ in the MRF422 PA all have a second harmonic attenuation A_2 of −21 dB and an A_3 of −32 dB.

TABLE 1

Properties of collector output circuits for a 75-watt class AB MRF422 PA tuhed for 7 MHz. Q_{design} and Q_{op} are explained in the text.

Matching network or matching network low-pass filter	Figure	Qdesign	Qop	Passband response (0.-1 dB MHz)	IL(dB)	A_2(dB)	A_3(dB)
LCL	4(A)	4	5.4	6.1-7.6	-0.143	-25.7	-40.0
CQL	4(B)	4	4.9	6.2-7.8	-0.123	-21.1	-32.4
LCC	4(C)	4	4.6	6.1-7.9	-0.122	-18.4	-29.2
CVD	4(D)	4	3.2	6.2-8.1	-0.098	-12.8	-18.3
TL	4(E)	3.55	6.9	4.9-8.1	-0.128	-29.7	-49.8
LCL-HWF	–	–	–	6.3-7.5	-0.242	-46.4	-88.5
CQL-HWF	–	–	–	6.2-7.8	-0.221	-49.4	-77.3
LCC-HWF	–	–	–	6.1-7.9	-0.221	-48.9	-77.6
CVD-HWF	–	–	–	6.2-8.0	-0.197	-41.4	-63.7
TL-HWF	–	–	–	5.5-8.0	-0.226	-59.9	-97.3

(The attenuation of the TL network depends on the passband width as well as the Q.)

Conclusion

Which collector matching network is best for an MRF422 PA? Because the composite responses of the 3-element networks are much the same for a given operating Q, the choice hinges on practical concerns like the ease of tuning and component values and ratings. Some networks — notably the CQL and CVD — are less suitable for medium- and high-power PAs. The series leg capacitors are 3000 pF or larger because of the large impedance transformation, and must carry a large current (3.5 amperes in the CQL). These networks are better suited to PAs in the 10 to 15-watt range, where both capacitance (for a given Q) and current are lower. The other networks, the LCL, LCC, and TL, are workhorses for PAs in the MRF422 class. Of these, the LCC is perhaps the most popular. It has only one coil and built-in DC blocking. The TL network is more difficult to tune (a spectrum analyzer and tracking signal generator are usually required to achieve the desired bandpass curve).

Even a modest programmable calculator can be used to design and analyze matching networks in conjunction with reactive sources and loads. I hope this article piques your interest in this important area.

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Article E HAM RADIO

WRITING THE TECHNICAL ARTICLE

By Joseph J. Carr, K4IPV, P.O. Box 1099, Falls Church, Virginia 22041-1099

While advertisers are the lifeblood of a magazine, and editors (and other staff) are the internal organs, the sinew and muscle are the non-staff freelance writers who contribute material to the magazine. That writer could be you! In this article I'm going to share some of what I've learned in the two decades since an Amateur Radio publication accepted my first article.[1]

First, let's get one matter straight right away. Technical writing is only a skill, and it's a skill that can be learned by almost anyone who has the brains to get an Amateur license. It is not an arcane art practiced by some specially talented mystical elite, but rather it's an attainable skill. And, you don't have to be an English major to do a good job (I made a "D" the first semester of college English 101 and flunked the third semester flat). I've written more than 50 books and 300 magazine articles, many of them for *Ham Radio*.

Slant

Not all articles are suited to all publications. The difference is what the trade calls "slant." This term refers to the point of view taken by the article in reference to the type of readers who buy the magazine. The same topic can sometimes be sold to several different magazines if the slant is different, the timing is different, and the magazines aren't generally in competition with each other.

The slant is merely your effort to aim the article at the readers of a particular magazine. Every editor can tell you something about his readers. You can also get a good idea of the readership by studying recent issues of the magazine. Using this information, you can "home in" on the types of article the magazine will buy. Although a few editors issue "want lists," most of them will tell you that they don't know what they want "but I'll recognize it when I see it."

Article format

There are several types of articles that appear in this magazine. Some are technical tutorial pieces, some are construction projects, and some are "how-to" pieces. Let's take a look at the basics of the how-to article. The common denominator for all how-to articles is that they offer instruction and advice. This definition covers a lot of territory, including most practical technical articles. There is no fixed universal format for all how-to pieces; almost any format will work some of the time. But there is one format that almost always works, so if you're a new writer, you might want to follow it until you have a little experience. The format, which I learned both at a writer's conference and from the editor of another Amateur publication, is called the "Tell-'Em-Cubed" method. Just follow this outline:

Tell 'em what you're gonna tell them.
Tell them.
Tell them what you told them.

The first "tell them" should be no more than about three paragraphs, and may be only one short paragraph. This "tell 'em what you're gonna tell them" segment must grab — and hold — the reader's attention, and convince him to continue reading. The main body of the article is the "tell them" portion and should occupy the bulk of the space. Finally, there's the "tell them what you told them" section for a quick (one to three paragraphs) summing up. Use it to highlight the main points, especially those that should be remembered.

For electronics articles there is a modified "Tell-'Em" format (which I call the "Ham Writer's Eight-Fold Way"):

Tell 'em what you're gonna tell them.
Tell what it's gonna do for them.
Tell them how it works.
Tell them how to build it.

Tell them how to test it.
Tell them how, when, and where to use it (as appropriate).
Tell them how to modify or adapt it for other applications.
Tell them what you told them.

Of course, not all of these elements need be included in every article, but it does represent a stylistic shopping list.

Writing the piece

Most successful authors prepare at least an informal outline for the article. This road map needn't be as formal as one for an English class; it's simply a guide to ensure that all bases are covered — and are covered in logical order. The outline keeps you on the right track.

Each major topic in your article deserves at least a paragraph. A major mistake novice writers make is to mix several topics in the same paragraph. If your outline is written to the paragraph level, you probably won't fall into this trap and your article will flow more naturally.

Another common mistake is to include too many topics in a single article. A magazine article is a capsule of information on a specific, usually quite narrow, topic. After my initial success in a ham magazine, I sent a manuscript to Jay Phipps, the editor of *Electronic Servicing*. Jay apparently saw something good in that mess of a manuscript, because he took the time to write a four-page bit of fatherly advice (not something one learns to expect from busy editors). He pointed out that there were at least four different articles in that one nine-page manuscript. When I finished rewriting the piece, it actually had five buried topics. Jay bought all five, just in time for Bonnie and me to get married.

How long should your article be? The quick-draw response is "long enough to tell the story," but (while true) that's not the practical answer. Take a look at the articles in *HR*. Most of them fall into a relatively narrow range of lengths that fits their format. In general, an article should be 5 to 10 double-spaced, typewritten pages with 2 to 6 illustrations. *HR* publishes longer pieces, and certainly some shorter pieces, but in general those that are bought fall in the midrange. If you feel strongly that an article needs a long treatment, write to the editor and make a proposal for either a long article or a multipart one. If the topic strikes the editor's fancy, you might get a no-obligation "speculative" go-ahead.

Preparing the manuscript

When you prepare the manuscript for your article, keep in mind that a real, live, warm-blooded editor must read and work with your piece. Prepare the manuscript to make his job easier. I've seen a lot of potential writers over the years who'd get fewer rejection slips if they did a better job of manuscript preparation. If an author is too sloppy to do the mechanical job correctly, the editor might get the idea that he's a little sloppy with the facts as well.

Editors require typewritten manuscripts, so don't even think about sending in a handwritten piece. Your typewriter or computer printer should be in good repair, and print well. If you don't have access to a typewriter or computer, there are secretarial services that can do the job. Dot-matrix submissions are accepted by most publishers, but only if they are easily readable. An editor spends a lot of time every day reading, so a washed-out, low-resolution dot-matrix submission might just go unread. A "near letter quality" dot-matrix printer with a fresh ribbon will produce an acceptable product.

Type the final manuscript on 8-1/2 x 11 inch plain white 20# paper. Don't use colored paper, or paper with rules. If you're sending a computer printout, be sure to use a middle to high grade of paper. The cheap stuff (which costs only a little less than the good stuff) leaves a coarse, ragged edge that annoys editors.

Don't send a manuscript that includes a lot of hand corrections. In general, most professional writers will retype a page if more than three minor corrections appear on it — and even then only if they use a typewriter instead of a personal computer word processor. Most editors don't mind if a typewritten submission has a few legible hand corrections, but don't overdo it.

When the manuscript is finished, bind the pages together with a single paper clip, not a staple. Also paper clip the illustrations to the text. In a technical article, the pictures are as much a part of the manuscript as the text, so don't forget them. Send the manuscript flat in a large manila envelope; don't bend it over and force fit it into a standard no. 10 business envelope.

[Note: A little word of advice for new writers. If you want to hear Terry Northup scream in anguish all the way from New Hampshire, just forget to place a list of captions on the illustrations package!]

Illustrations

"A picture is worth a thousand words" says an old cliche. That old saw might be true in some cases, but when you're being paid on a per page basis, a picture is worth about 200 words. The real value of the picture, however, is that it enhances the article and makes it easier to follow. In fact, for technical articles, the picture might make it possible in the first place. A picture, in that case, isn't worth a thousand words — it's priceless.

Your illustrations don't have to be drawn profession-

ally. Pencil drawings are acceptable, but must be done in a way that can be interpreted by the magazine's artist. Use some sort of coarse grid graph ("quadrilled") paper, or an engineering sketch pad for your drawings. The latter are green or yellow tablets that are blank (with border) on one side and gridded on the other. The grid lines show through to the blank side enough to guide you in making the sketch, but do not appear on the picture.

The basic requirement for illustrations is that they be understood by the editor and the artist. The line drawing should be neatly done and contain all necessary information. For schematics, that requirement includes component values and semiconductor device type numbers. Keep in mind that there are different drawing practices in effect at different magazines. For example, *HR* uses "CR1" for the first diode in a circuit, not "D1." Also, they use the chassis ground symbol unless an actual earth ground is intended. Study *HR* illustrations to see which symbols they use.

Photographs are also very useful for illustrating the technical article. There are some general guidelines for taking photos. Don't use low-cost 110 or disk format films. Use 35-mm or larger (e.g., 120 or 220 size) film, even if you have to borrow a camera. The old 126 cartridge film (basically a form of 35-mm film in an *Instamatic®* cartridge) is useful if you have a good quality camera. Use black and white film like: *Verichrome Pan*, *Panatomic-X*, *Plus-X*, *Tri-X* or their equivalents. *Do not use color print film*. Some magazines can sometimes use slides, but check with the editor before you hang your piece on a color transparency. A photo laboratory can make a black and white print from your slide by shooting a black and white internegative from your transparency.

The print should be glossy, with borders (you may have to ask for them), and be either 4×5, 5×7, or 8×10 inches. Keep in mind that 35-mm negatives may not reproduce well as 8×10s. Place your photo in a celluloid "page protector." These are available at office supply stores for about 50 cents each. Tape the photo to the inside paper in a way that keeps the tape off the print. (See why you need to order bordered prints instead of the borderless type that's now standard?)

The "standard" lens that comes with most 35-mm cameras has a fixed focal length on the order of 48 to 55 mm. It's almost useless for anything but snapshots without an add-on device like a macro (close-up) lens, close-up bellows, or close-up rings. I use several different lenses for my pictures: a 28-80 mm Zoom Macro, a 70-210 mm Zoom Macro, a 50-mm "snapshot" lens fitted to a close-up bellows for really close-up shots, and 105-mm Macro lens. What's a "Macro" lens? Basically, it's one that lets you do close-up photography, that's all. While photographers may have a more rigorous definition, the point of owning a Macro lens is to allow you to focus closer than the standard 2-3 feet common on non-Macro lenses.

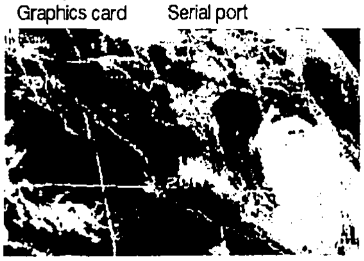
Conclusion

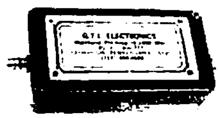
There are any number of reasons why you might want to write a technical article: it pays money, it brings recognition, it helps the Amateur Radio hobby, and it's a heckuva lot of fun. And guess what? YOU CAN DO IT!

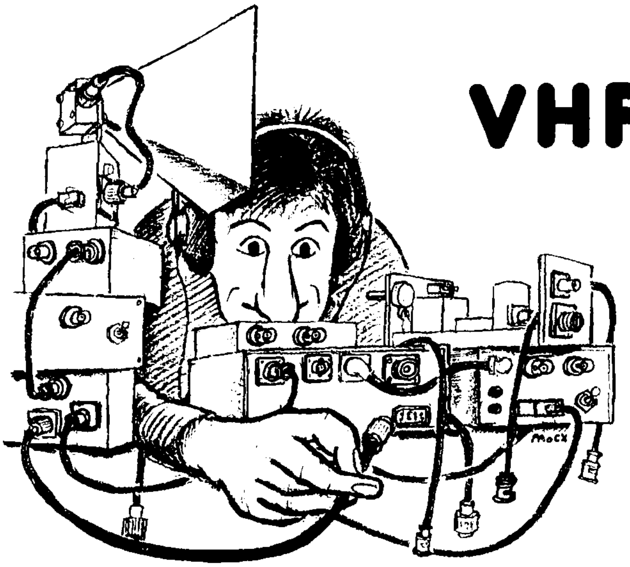
Reference

1. Joe Carr, K4IPV, "Kill That Mobile Noise," *QST*, July 1968, page 36.

Article F **HAM RADIO**







VHF/UHF WORLD

Joe Reisert, W1JR

DX records on 50 MHz and above

Many HFers have worked all the current DXCC countries. Some DXers have even worked and confirmed all current countries on the ARRL DXCC list on 20 meters. Eventually someone will work all current countries on all HF bands; the radio propagation is available.

Several Amateurs presently operating on 50, 144, and 432 MHz claim DXCC totals of 50 to 95 countries on these bands. One day, perhaps in the next few years, 6 and 2-meter DXCC will become a reality using a combination of F2, TE, E_S, and EME propagation.[1-4] But it probably won't be possible to work all current DXCC countries on 50 MHz or above — at least not in a normal lifetime. Even EME has its limitations!

There are many reasons precluding this achievement. Each IARU region has different and often incompatible frequency assignments above 29.7 MHz. The main impediment to working "long-haul" DX above 50 MHz is that the propagation modes required for DX are seldom available, except via EME. Those Amateurs that operate above 50 MHz have had to establish a different "yardstick" to measure performance against their peers.

For many years North American VHF/UHFers worked hard to attain a WAS or WAC award. "Locators" were sought in Europe. The ARRL VUCC (VHF/UHF Century Club) award has been a standard since 1983.

Yet even these awards are not a good measurement of an Amateur's capabilities on the frequencies above 50 MHz. Your actual location on the earth has a great bearing on your maximum DX possibilities. Tables were compiled of the longest DX worked on each Amateur band above 144 MHz. This worked up to a point, but soon became ineffective once someone worked across a special exclusive propagation path (i.e., from California to Hawaii, across the Mediterranean Sea, or the Great Australian Bight).

I started publishing a table with a different twist — one that recognized DX achievements in North America, based on the "suspected" propagation mode used.[2] I also developed similar worldwide and EME tables.

This new table first appeared in "VHF/UHF World" in 1985 and has changed many times. It's been improved and expanded with each new frequency, propagation mode, and claim. I've also added six-digit grid squares. The latest update appeared in "VHF/UHF World" of June 1988.[3]

Why the emphasis on VHF DX?

Many Amateurs move up to the VHF frequencies to improve local coverage; they do it to ragchew, or pass traffic with little or no QRM. These operators want to avoid DX and all its trappings! Still others enjoy the vast networks of VHF/UHF packet and FM repeaters, especially for wide area mobile coverage and emergency traffic.

Many 2-meter and above users are often unaware that they can work DX on these bands. They think that working beyond line-of-sight (LOS), or perhaps over 50 miles, isn't possible except in rare instances — and then only with an enormous antenna and lots of experience.

Those Amateurs who operate the VHF/UHF frequencies seriously know that coverage is possible out to several hundred miles at almost any time of the day or night using CW or SSB, moderate power (50-100 watts), a Yagi with an honest gain of greater than 10 dB, and a receiver with a low noise figure (less than 3 dB).

VHF/UHF DX must be quantified. On 6 meters there are several propagation modes not commonly available on 2 meters and above. The mode of propagation is often difficult to determine because many contacts involve a "mixed" propagation mode (combinations of F2, E_S, TE, MS, or backscatter).

Long-path contacts have been reported during the rare times when F2 propagation is present on 6 meters. In

these contacts, the direction of propagation between stations is reversed and the signals cover distances exceeding half the earth's diameter or 12,430 miles (20,000 km). Because of their rarity, claimed 6-meter records (excepting EME) aren't included in most record tables.

So why the emphasis on DX on VHF and above? The reasons are many but the old saw still applies: "Because it's there." But that's not enough of an answer.

There are many other reasons to "seek out" DX on the higher frequencies. Successful record-breaking VHF/UHF DXing requires a unique knowledge of radio propagation and a certain amount of luck. But even the routine fallouts of VHF and above DXing are tremendous. A few that come to mind are:

• Discovering new modes of radio propagation.

• Determining the maximum capabilities of each propagation mode. (This includes the optimum times, days, and years and the necessary weather conditions, if applicable.)

• Choosing the optimum transmission mode (CW/SSB/FM, etc.) for each mode of propagation.

• Finding operating techniques that maximize data throughput.

• Unearthing equipment improvements like more stable local oscillators, lower noise weak signal receivers, efficient higher gain antennas with low side/grating lobes, and more efficient transmitters.

References 1 through 6 describe most of the known radio propagation modes available above 50 MHz. By familiarizing yourself with these references you can determine the capabilities and limitations of each mode, and try to expand upon them.

Determining the optimum equipment, operating techniques, and transmission mode greatly improves DXing results. For instance, CW is still the best weak signal technique — especially where only low data rates (like EME) are required. CW was used in the early days of meteor scatter propagation, but SSB is now widely used because it improves productivity by increasing the data rate.

In the "good old days" Amateurs used FM to great advantage on microwave LOS communications. Schemes like polaplexers circumvented the need for high stability oscillators.[7] State-of-the-art (SOA) improvements in local oscillator technology have increased the popularity of CW and SSB, and microwave records are falling like stones.

Most improvements resulted from the hard work of VHF and above weak signal DXers who wanted to develop the SOA in equipment, increase propagation knowledge, and set new DX records. We now have Amateurs using CW and SSB all the way up through 47 GHz[8]!

How are DX records broken?

This isn't a simple question. In most cases it's quite a challenge to break an existing DX record, and that takes a serious effort. You may need new equipment with greater capabilities than are presently available. Special locations and weather may also be required.

In other cases, an existing VHF and above DX record has actually been broken by accident, sometimes without the knowledge of either one or both of the new record holders! The fallout in this case may be great, as a new propagation mode or method is discovered to extend an existing record.

If you decide to challenge a DX record, examine carefully the existing records shown on the tables in this column. Study the characteristics of the particular propagation mode and record you expect to challenge. Finally, develop a plan of attack.

Each VHF and above DX record is listed by frequency and propagation mode with the callsigns of the record holders, grid locator, date, mode, and the actual DX attained in miles and kilometers. The DX shown is calculated using the best available information.

The distance shown on the tables is based on a "spherical" earth model. This is by far the most common distance determination method used by Amateurs because it employs simple mathematics and straightforward computer programs.

Spherical earth calculations have some inaccuracies depending on whether one or both of the stations are near the earth's equator or poles. The greater the distance involved, the greater the inaccuracies — but they probably never exceed about 44 miles (70 km) worst case.

In the future, I expect to convert the DX record tables to a different mathematical formula using an "ellipsoidal" earth model. This will improve record accuracy, but I doubt if anyone will lose or gain a claim!

I haven't converted to this more accurate method because few Amateurs seem to have used, or have access to, these more sophisticated models. A changeover at this time could cause confusion, and make it difficult to compare records.

In the meantime, if you'd like to try it, *The Radio Amateur's World Atlas*[9] describes a computer program for determining ellipsoidal earth distances. I can't testify to it s accuracy at this time, but hope to do so shortly.

My DX record information comes from the VHF/UHF/SHF Record Verification Forms you submit. (The form was shown on **table 4** of last June's "VHF/UHF World" column.[3]) I retain all claim forms for my record file. The grid locator shown on the records is derived from this information. This means the DX shown may not be the same as what you'd calculate using some of the new computer programs based on the center of center DX between two grid squares.

It's very important that all record information you send be as complete as possible. Accuracy is the key.

I try to include as much new information as possible on each new DX record submitted at the end of each "VHF/UHF World" column. This helps new record challengers gain

insight into the required equipment and parameters. More on this shortly.

New DX records

Generally speaking, it's rare when more than two VHF and above DX records are broken in a single month. Usually it's easy to summarize the new ones at the end of the column. But, so many DX records have been broken lately that it's been tough to keep up with the influx of telephone calls and paperwork. In the last few months, some of the same records have been broken three or more times! I finally decided that the fair thing to do was devote this month's column and the next to those records that have arrived recently, and have been fully documented.

This record DX activity is a great testimonial to the interest in and health of the VHF and above frequencies, as well as the challenges and advancement in the SOA. Who says we aren't utilizing our present frequencies adequately?

New ionospheric records

I've tried to find some way to arrange this new record material in an orderly fashion, but it's difficult. New records are coming in faster than I can get them out to you. I decided to break the new records into four separate categories: ionospheric, tropospheric, EME, and light waves.

144 MHz. For many years the North American 2-meter sporadic-E DX record was a "single-hop" contact. In the early 1980s there were probable "double-hop" contacts with some ducting. Then, in the June 1987 VHF contest, the first clear double-hop 2-meter contact was made in North America[4].

Now I've authenticated a new record that extends the 1987 one considerably. On June 6, 1988, at about 0230 UTC, stations in Alabama were working Colorado stations on 144.2-MHz SSB. Then, at about 0235 UTC, John Howard, KB4WM, Childersburg, Alabama (EM63TG) worked Merle Cox, W7YOZ, Kirkland, Washington (CM87VR) for a new DX record of approximately 2106 miles (3,389 km). At 0237 UTC KB4WM broke his own record by working Larry Logan, NF7X, Everette, Washington (CN87VX) for an approximate distance of 2111 miles (3,397 km). This was followed at 0250 UTC by Dale Peterson, WA4CQG, Auburn, Alabama (EM72FO) who jumped on frequency, worked W7YOZ, and extended the record even further. So, unless I hear to the contrary, the latest 2-meter sporadic-E record stands at 2172 miles (3495 km).

Both WA4CQG and W7YOZ were running about 400 to 500 watts on SSB with four 16-element and one 14-element Yagis, respectively. Signals were Q5, but only around the S4-5 level.

Remember that these contacts were still not coast to coast. A further extension, perhaps by as much as 500 miles, is still possible. Any challenges to this great opening?

220 MHz. Now let's look at the meteor scatter records. The first case involves 135 cm. This band is usually devoid of meteor scatter activity, except during the Perseids meteor shower. This year was no exception.

This year's Perseids shower was generally rated as poor — surely poorer than last year — by most 135-cm aficionados. This didn't dampen anyone's enthusiasm, but it did decrease longer distance contacts. They were few and far between.

But, after five years of trying to work each other, W1JR, Chelmsford, Massachusetts (FN42HN) finally completed a meteor scatter contact on 220.1-MHz SSB with Ron Roche, KØALL, Fargo, North Dakota (EN16OU) between 0500 and 0700 UTC on August 13, 1988 during one of several marathon sessions. We completed the contact by piecing together many short and relatively weak SSB bursts, none lasting more than a single call set at my end.

Both stations were running 600 to 1000 watts with single long boom Yagis. KØALL was also on one end of the previous 135-cm meteor scatter record. Ironically, we increased the dis-

tance over that record by only one mile!

If you examine the table in reference 3, you'll note a peculiar difference. The new record appears to be shorter than the previous one. But, before you suspect collusion, note that KØALL's grid square has changed.

When Ron rechecked his latitude and longitude after our contact he found out that they were listed incorrectly in the past. Anyway, the distance from KØALL to W1JR is still one mile further than the distance from KØALL to K1WHS, the previous record. This points out only too clearly the importance of verifying your longitude and latitude with the greatest of care. Enough said.

432 MHz. After several years of trying, I've finally verified the exact location of WØLER who was on one end of the longest documented 70-cm meteor scatter contact. As a result, that record distance has increased about two miles and will be reflected in the updated table.

Tropospheric records. Warmer weather typically brings good tropospheric propagation in North America. It also encourages lots of expeditions to the seacoast and the mountaintops. Expect to see lots of record attempts during these months.

This year was no exception. In fact, I think I was aware of more record attempts this past summer than a year ago — despite the fact that it's getting more difficult to find a record to break. Many of these expeditions were successful.

220 MHz. The tropospheric record on this band stood for a long time but it has now been broken. On September 9, 1988 there was some peculiar tropospheric ducting from Arkansas to some of the mountaintop stations in New England. Those of us who live at lower elevations in New England listened carefully, but the signals were going right over our heads!

At the same time hurricane Florence was whirling around just south of New Orleans, Louisiana. This apparently contributed to the very high barometric pressures in the Northern and East-

ern United States, and fed lots of warm moist air northward from the Gulf of Mexico.

At 0340 UTC Dave Olean, K1WHS, West Lebanon, Maine (FN43MK) and Rick Roderick, K5UR, Cabot, Arkansas (EM35WA) worked on 2 meters with good signals. Then they moved up to 220 MHz and quickly worked each other on CW at 0346 UTC with 559 to 579 signals.

The distance, 1267 miles (2039 km), is an extension of 85 miles over the previous record. Dave was running 1500 watts to four 17-element "Boomers" stacked vertically; Rick was running about 135 watts to a single Yagi of the same type.

3456 MHz. When you move up into the microwave bands, especially above 2450 MHz, it takes lots of luck to find a distant station at a record distance. Expeditions are usually organized to break the DX records. On August 7, 1988 Loren Libby, KX0O/0, traveled up to the top of Pike's Peak, Colorado (DM78KU) at 14,110 feet above sea level (see **photo A**)! At 1700 UTC he completed a CW contact on the 9-cm band with Dan Osborne, WB5AFY, Vernon, Texas (EM04ID) for a new DX record of 455.5 miles (733 km). Signals were 8 to 12 dB out of the noise in a 2-kHz bandwidth. Loren was running 13.5 watts into a 32-inch diameter dish and Dan was running a TWT at 250 watts to a 6-foot dish.

5760 MHz. Jim Crew, WA5ICW, and Larry Nichols, W5UGO, were also out traveling. In July, they were in the South Central states working portable on the 5-cm band. They regularly use 4-foot dishes for record attempts, but this time they decided to think big. Both brought along 10-foot dishes on trailers!

On July 9, 1988, Jim set up near Boise City, Oklahoma (DM86SR) and contacted Larry operating near Sand Springs, Oklahoma (EM16WD) on 5760 MHz using SSB — a new record distance of about 351 miles (564 km). The power was 5 watts with 10-foot dishes at each end. Signals were 30 dB over S9, despite a thunderstorm near the midpoint between their stations.

PHOTO A

This photograph shows Loren Libby, KX0O, operating from the top of Pike's Peak near Colorado Springs, Colorado while setting the new 3456-MHz DX record.

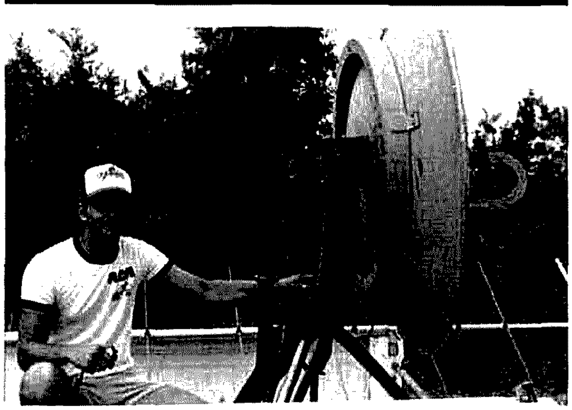
PHOTO B

One of the participants in the new 5760-MHz DX records was WA5ICW using his 10-foot "portable" dish setup near Moses, New Mexico.

PHOTO C

The 10- and 4-foot dishes setup by W5UGO near Sand Springs, Oklahoma.

PHOTO D



N5JJZ and a 4-foot dish setup near Broken Arrow, Oklahoma.

Not satisfied with their record and the strong signals, Jim drove further westward to a location near Moses, New Mexico (DM86LR). Then about 1200 UTC on July 10, 1988, he worked Larry again for another new DX record at a distance of about 377.4 miles (607 km). Signals were 30 dB over S9. Larry then tried a 4-foot dish and signals dropped to 10 dB over S9. Still not satisfied, Larry changed his antenna to a small test horn and signals were still S9!

Then at 1256 UTC Jim broke the new record once more. This time he contacted Scott Brillhart, N5JJZ, Broken Arrow, Oklahoma (EM26CB) — a new record distance of 404 miles (650 km). Signals were S9 on SSB. Scott has a 4-foot dish and runs 5 watts. **Photos B, C, & D** show some of the setups used to make these new DX records.

10 GHz. Meanwhile, 3-cm expeditions were operating on both the Eastern and Western United States coasts. On July 10, 1988, a group of San Diego microwavers set out to break a new DX record using wideband FM (WBFM) on 10.250/10.280 GHz. The southern end of the path was operated by N6CW/XE2GDK, K9VV/XE1FUX, WA5LIG/XE2GBO, K6JYO, and N6XQ operating at various locations on Baja California Sur, Mexico (DM10/DM11).

Operating under the callsign XE2GDK and running at only 10 mW of WBFM into a 4-foot dish, they worked W6OYJ at 80 miles, WB6NOA at 176 miles, W6KGS at 216 miles, N6CA at 265 miles, and W6CPL at 280 miles.

Next XE2GDK operated from San Quinton, Mexico (DM20), and worked N6CA/6 just north of Santa Barbara, California (DM04) at a distance of 356 miles. A few minutes later XE2GDK worked their longest DX, Gary Field, NN6W/6, located about 10 miles northwest of Santa Barbara (also DM04) at a distance of 358 miles. NN6W/6 was running 15 mW into a 19-inch dish.

All the stations in these tests were operating Gunnplexers® full duplex using 30-MHz i-fs. While these contacts weren't DX records, they were WBFM records and came pretty close

to the narrowband record. Stay tuned; there's more to this story.

Other California 3-cm narrowband enthusiasts were out trying to extend the 1987 mountaintop records. On August 6, 1988 at 1156 UTC (4:56 AM PDT!), Bruce Erickson, WB0HLC/6, operating from Frazier Mountain, California (DM04MS) — one end of the previous DX record — completed a CW contact with Lynn Rhymes, WB7ABP/P on Bonanza King Mountain, California (CN81QB). This set a new North American DX record of 479 miles (770 km). At 1300 UTC the signals were strong enough that they used SSB.

Bruce was running about 700 mW to a 32-inch diameter dish and Lynn was running the same power into a 48-inch one. Bruce reports that he now has an FSK (1100 Hz shift) beacon on 10.36802 GHz in operation atop Mt. St. Helena, CM88QQ. The beacon runs 10-mW ERP to a vertical omni antenna and 120-watts ERP to a 12-inch dish with horizontal polarization aimed at a 142-degree heading intercepting the Diablo, Pinos, and Frazier Mountains to the south.

During early August, several stations in the Northeastern United States were trying long-haul coastal tropo on 3-cm using narrowband systems. One station was set up on Cape Cod, Massachusetts (near FN51AQ) looking to the southwest down the Atlantic coastline. Unfortunately the ducts didn't cooperate, so they were unable to work beyond about 200 miles. Others may try this path shortly.

During the September VHF contest, several members of the San Diego microwave group I mentioned earlier decided to try another attempt for the 3-cm DX record. This time one group traveled further south and operated from a site at 750-feet ASL near Guerrero Negro, Baja California Sur, Mexico (DL27VL). You can spot this location easily on the ARRL grid map[8] — it juts way out from the peninsula.

On September 10, 1988, at about 1545 UTC, XE2GFH (N6XQ and WA5LIG, operators) worked Chip Angle, N6CA/6 at Palos Verdes, California (DM03TS) for a new North American 3-cm DX record of about 498 miles. Both stations used 4-foot dishes and WBFM Gunnplexers at 80 and 10 mW, respectively. Shortly thereafter, AA6Q, WA7CGR, and WA6MEM joined Chip at Palos Verdes, and also worked XE2GFH with 10 to 50 mW and antennas as small as a 17-dB gain horn!

Not to be outdone, Chip then moved north to Beverly Hills, California (DM04SC) to an elevation of 2000 feet ASL and tried to extend his record. At 2200 UTC the record was extended to 522 miles! Signals were up to 25 dB out of the noise on peaks.

Meanwhile, Gary Field, NN6W/6 was operating near Santa Ynez Park, California (CM94XM) at a 3000-foot elevation and heard XE2GFH most of the day. However, XE2GFH couldn't copy him well enough on voice to complete a contact.

Finally at 0004 UTC on September 11, they made a complete contact using MCW for a new 3-cm DX record of 595.3 miles (958 km). Gary was running 15 mW with a 30-inch dish.

These primarily over water extended contacts bring up an important point. For some time I've been wrestling with a few critics about the differences in my designation of ducting and tropo as shown on the North American records table between 144 and 1296 MHz.

I feel strongly that contacts that are at least 75 percent over water have an unfair advantage on 2 meters and above, because low-attenuation ducting is often present (not to mention the normal superior refraction index over large bodies of water).[6] The path from California to Hawaii is the principal example. For this reason, I have treated over-water contacts as a separate category to avoid discouraging or competing directly with overland tropospheric records.

To further clarify this point, I'll be modifying the tables slightly. The tropo records previously shown will remain, but they'll be reclassified as Tropo OL (over land). Those contacts shown as ducting (which are at least 75 percent over water), will now be designated as Tropo OW (over water).

This, in effect, will open up a new category for records on all bands above 1300 MHz. But, in order to qualify for the tropo OW record, you'll have to exceed the distance of the tropo OL record on the respective band. Fair enough? I invite your comments.

47 GHz. Meanwhile, during the ARRL UHF contest, the microwavers up in the Northwestern United States were also active and trying to beat their own 47-GHz record. Tom Hill, WA3RMX/7, set up at Crater Lake, Oregon (CN82VW) and the Tektronix Radio Club operating as K7AUO/7 (W7ADV, K7RUN, and WA7GFP, operators) was on Mt. Ashland, Oregon (CN82PB). Both stations were at approximately 7300 feet ASL.

At first there was cloud cover at Mt. Ashland and no signals were copied. However, at 2145 UTC on August 6, 1988 the clouds lifted, the path was visually clear, and CW reports were exchanged. Shortly thereafter, the signals increased in strength and SSB communications were used.

The equipment involved was all designed and built by Tom Hill using a combination of surplus, new, and homebrew components and converters. At Crater Lake the power was 3.5 mW to a 28.5-inch dish. At Mt. Ashland the power was 4.3 mW into an 18-inch dish. Both stations operated on 47.040035 GHz (USB).

This new DX record is quite an achievement. The distance is 65.4 miles (105.2 km) — a significant increase over the previous one. In addition, this record exceeded the old worldwide record by about 25 percent. The contact was made using narrowband systems and on SSB. It's probably the highest frequency where two-way communication has ever been conducted using SSB, especially at this distance.

Summary

This month I've discussed how VHF/UHF and above DX records are made, along with their relative impor-

tance to Amateur Radio and the SOA. I also reviewed some of the most recent record-breaking contacts using ionospheric and tropospheric propagation.

Next month's column will discuss recent EME and light wave DX records. At the conclusion of February's column, I'll give you the latest updated DX record tables.

Final notes: Some important matters such as "band plans" and the restructuring of our 220 to 225-MHz band have recently occurred, but will have to wait until later. In the meantime, please examine the present ARRL band plan for the 220 to 225-MHz band (shown in recent *ARRL Repeater Directories).*[10]

You'll notice that I reserved the spectrum from 222.0 to 222.3 MHz when I chaired the writing of this band plan back in 1978! In the event that the FCC does remove the 220 to 222-MHz portion of the band, and if no Amateurs violate the existing band plan, 222 to 222.3 MHz would still be available for "protected" weak signal operation away from FM repeaters.

Feedback: In the October 1988 column of "VHF/UHF World" two graphs were mistakenly reversed, changing the meaning of the information that followed. To correct this, interchange graphs "C" and "D" in **fig. 1** on page 72.

Important VHF/UHF events:

December 21	*± 1 month. Winter peak of sporadic-E propagation*
December 22	*Predicted peak of the Ursids meteor shower at 0330 UTC*
January 4	*Predicted peak of the Quadrantids meteor shower at 0030 UTC*
January 6	*New moon*
January 10	*EME perigee*
January 14-16	*ARRL VHF sweepstakes contest*

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5. Joe Reisert, W1JR, "VHF/UHF World-Microwave and Millimeter-wave Propagation, Part 1," *Ham Radio*, July 1986, page 82.
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8. Joe Reisert, W1JR, "VHF/UHF World-Operating a VHF/UHF Microwave Station," *Ham Radio*, July 1987, page 48.
9. Folke Rosvall, SM5AGM, *The Radio Amateur's World Atlas*, available from the **HAM RADIO** Bookstore for $3.95, plus $3.50 shipping and handling.
10. *The ARRL Repeater Directory*, 1987-88 edition, available from the **HAM RADIO** Bookstore for $4.00, plus $2.50 shipping and handling.

Article G **HAM RADIO**

ELMER's NOTEBOOK

Tom McMullen, W1SL

Transistors and how they work

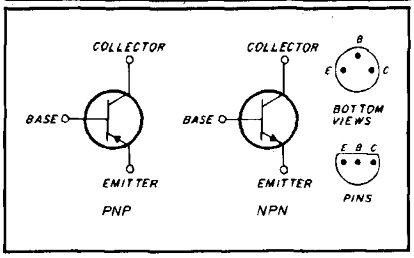
Transistors have been with us long enough that almost everyone has had some exposure to them in electronic equipment of one type or *another*. Almost any piece of radio gear around today contains some of these devices. Many new Amateur transceivers are totally dependent upon some transistors or semiconductors for their operation. When these devices first became commercially feasible, many articles were published explaining how the tiny bits of metal and plastic worked and what was inside their miniscule packages. I won't go into the "conventional" explanation involving holes, electron pairs, valence bonds, and all the rest — we're not interested in building transistors, just understanding how they work.

Transistor types

Transistors are divided into two basic classes: bipolar and field effect. I'll stick with bipolar types for this month, and look at field-effect transistors some other time. (There are several variations on these themes — devices called MOSFETs, IGFETs, junction transistors, unijunction transistors, mesa transistors, planar transistors, etc. I'll just cover the basic types here.)

In the bipolar transistor category, there are two types once again: NPN and PNP. These type designations reflect the makeup of the layers of semiconductor material in the transistor. **Figure 1** shows the schematic symbols for NPN and PNP transistors, plus the most common pin arrangements for either type. Knowing which is which can help when you're troubleshooting a piece of equipment without a schematic. I've always used a couple of trick phrases to identify them and note the appropriate polarity of their supply voltage.

FIGURE 1



Schematic symbols for NPN and PNP transistors, along with the most common pin or lead arrangements for either type.

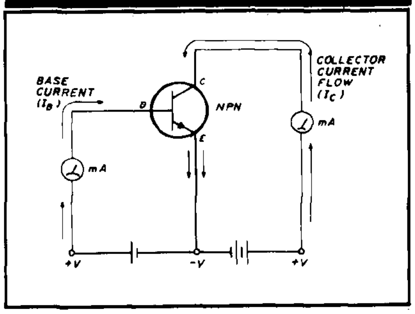
Look at **fig. 1**. There is an arrowhead drawn on one of the lines inside the symbol. This represents the emitter of the transistor. I use this arrowhead as the clue to the transistor type: **N**ot Pointing i**N** tells me that is an NPN transistor. Pointing i**N** Positively indicates a PNP transistor. These type designations (NPN and PNP) also give a clue to the voltage polarity that is applied to the collector. Use the center letter of the type designation as the indicator — n**P**n tells you that the collector is connected to the Positive (+) side of the supply (through resistors, transformers, RF chokes, etc.). In the other type — p**N**p — the collector is connected to the Negative (−) potential. (This, too, can be through transformers, resistors, RF chokes, or whatever.)

How do they work?

Bipolar transistors are current-amplifying devices. This means that a current made to flow into their input terminal (see base current in **fig. 2**) will directly affect the flow of current in the output circuit (the collector and associated components). Both base and collector currents flow through a common element, the emitter. The names of the emitter and collector elements describe what they do — the emitter emits electrons, and the collector collects them. But what in the world is a "base?"

This term comes from an early transistor design in which a base layer of semiconductor material was deposited

FIGURE 2



Base current (abbreviated I_B) through the base/emitter circuit causes a greater current (I_C) to flow through the collector/emitter circuit.

on some type of insulator, and then a slightly different type of material was deposited on the base layer to form the emitter and collector. The emitter and base layers function very much like a diode — in fact, some applications use the diode action of these two layers as part of a circuit design. One that comes to mind is a temperature-compensating circuit that maintains the correct bias in a power-amplifier circuit.

Transistors are low-impedance devices because they operate on current flow. This may be a new experience for those familiar with the old vacuum-tube technology. The input to the grid of a tube is high impedance, usually in the thousands of ohms. It's not unusual for the input impedance to a power transistor circuit to be in the single digits, or even less than 1 ohm. Even low-power amplifiers for audio or RF signals can have input impedances in the range of tens to hundreds of ohms.

This is where circuit designers earn their keep. Instead of a simple parallel-resonant circuit, you need a series-resonant circuit with a low-impedance output, or a combination of L/C networks that will provide impedance matching and selectivity at the same time. Considering the savings in space and power consumption, it's a very good tradeoff.

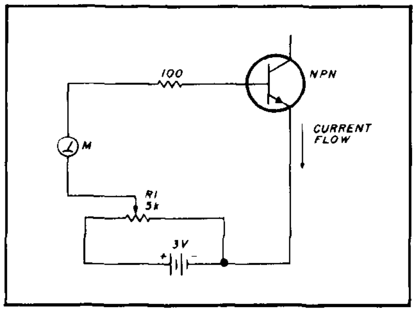
An experiment

All this looks good on paper, but what happens when you hook one of these devices up? I decided to try a simple experiment to find out. (I did the same thing with Ohm's law years ago. I found a precision 1-ohm resistor and hooked it to a 1-volt supply to see if Georg was right. He was!)

The transistors I used are garden-variety types available from flea-markets, supply houses, or mail-order firms in plastic packs of 10 or 20 for $1. My package was marked "2N2222 equivalent." I used common AA cells as the power source, along with a couple of milliammeters and a handful of clip leads.

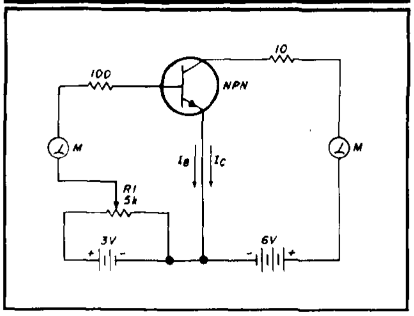
I first tried to see if the emitter/base part of a transistor was really a diode. Using the hookup shown in **fig. 3**, I measured the current flow with the positive voltage connected to the base through a 100-ohm current-limiting resistor. Sure enough, a small current began to flow as I changed the value of R1 to place voltage on the base. The current was approximately 20 μA at 0.45 volt and increased with voltage up to the point where 0.7 volt produced 2 μA of current. I stopped there rather than risk burning out the base/emitter junction. I then reversed the voltage polarity; the current flow was almost nonexistent. Increasing the voltage up to the full 3 volts of the supply produced only 30 μA. Diode action was confirmed. (You can perform this same experiment using an ohmmeter if you're sure which lead of the meter has the positive (+) voltage.)

FIGURE 3



The base/emitter junction can be tested with this setup. For most small transistors, the meter can be 0–100 μA. Check for reverse leakage by reversing the polarity, just as in a diode.

FIGURE 4



Setup used for checking collector current versus base current. The base-current meter was 0-100 μA, and the collector-current meter was a switchable VOM on the 0-10 and 0-100 mA ranges.

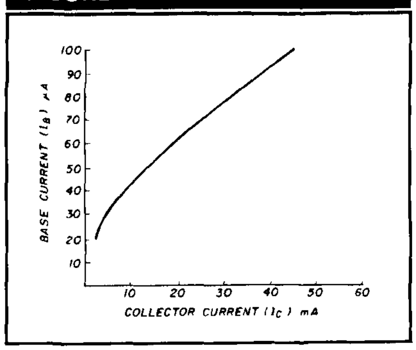
Now that you've explored the base/emitter theory, it's time to try the rest of the device. It takes a few more clip leads, a second milliammeter, and another resistor. The setup is shown in **fig. 4**. (I always use current-limiting resistors or fuses when experimenting — major meltdowns on the workbench are messy and the smoke sets off alarms *all over the house!*)

I found that increasing the current through the base by varying the value of R1 does indeed cause current to flow in the collector circuit. Two mA of collector current flowed with 20 μA of base current. Increasing the base current up to 100 μA caused a collector current of 45 mA. I stopped at that point because the transistor was getting warm to the touch. **Figure 5** is a graph of base current versus collector current.

Once again, the theory seems to fit what the experiment has shown. (Or is it the other way around?) — Bipolar transistors are current-manipulating devices. Where does the name "bipolar" come from? There are two kinds of material in the makeup of the transistor: P-type and N-type. The arrangement of those two types in the "sandwich" determines whether the device is PNP or NPN.

I performed the same experiment on an equally unknown PNP transistor and, once again, it worked just as the theory said it would. I had to reverse

FIGURE 5



A plot of base current and collector current measured using the setup of *fig. 4*. Be aware that some exotic UHF or low-noise transistors can't stand this type of test. If you experiment, use inexpensive or surplus devices. *(continued on page 100)*

A 3456 MHz LINEAR TRANSVERTER

By Dave Mascaro, WA3JUF, RD 1 Box 467, Ottsville, Pennsylvania 18942

Over the past few years Amateur microwave activity in the United States has increased dramatically. Many operators active on 1296 MHz have put their stations on the 2304-MHz band. Stations work 10-GHz SSB/CW, as well as wide-band FM with Gunnplexers® There's more commercial equipment available for all bands up to 10 GHz. Homebrewers are using surplus TV receive only (TVRO) and outdated commercial equipment to build up to the next higher band, 3456 MHz.

As with other bands up to 2304 MHz, the main modes of communications on 3456 MHz are CW and SSB. There are many ways to generate RF power on this band — both CW and linear. Frequency multipliers with step recovery diodes (SRD) and active multipliers are used for CW, FM, beacon transmitters, and local oscillators. You can use linear transverters for SSB/CW and all other modes, just like on the 50 through 2304 MHz bands.

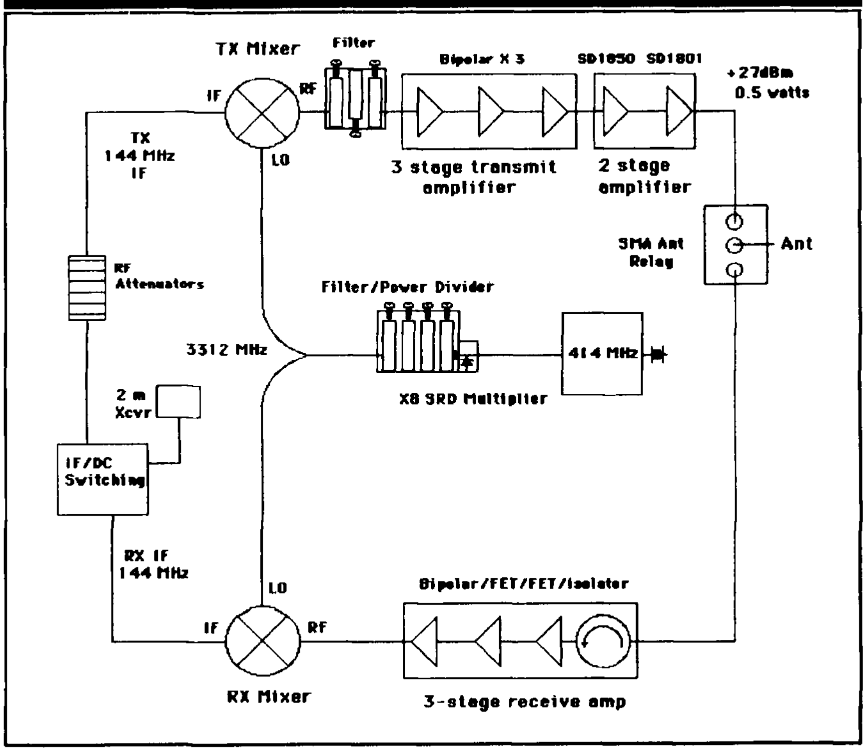
Figure 1 shows the block diagram of a 144 to 3456-MHz transverter. The transverter transmit and receive mixers use a common local oscillator at 3312 MHz. The 144-MHz transmit i-f is mixed with the local oscillator to produce 3456-MHz transmit signals. During reception, the 3456-MHz receive signals are mixed with the local oscillator to produce the 144-MHz receive i-f signals. A 2 or 3 section interdigital filter follows the transmit mixer to attenuate out the local oscillator and image frequencies.[1,2]

I didn't use a 144-MHz i-f post amplifier after the receive mixer. Unlike the 28-MHz "front end" in an HF transceiver that is normally used *for* a transverter, modern 2-meter transceivers have good front ends with plenty of gain. A post amplifier only makes the resting S-meter readings higher. The system noise figure is established in the 3456-MHz LNA.

Receive portion

Receive signals from the antenna relay are amplified by one-half of a modified TV receive only low-noise amplifier (TVRO LNA). The other half is used in the transmit portion of the transverter. My first modification involved installing an SMA antenna connector in place of the waveguide antenna input.[3] Normally a scalar-type feed horn is attached

FIGURE 1



Block diagram of a 144-MHz to 3456-MHz linear transverter.

directly to the LNA when used in a satellite receiving system. A feedthrough cap is also installed to bring +15 Vdc into the LNA housing without using an external bias-T attached to the output "N" connector.

Split TVRO LNA

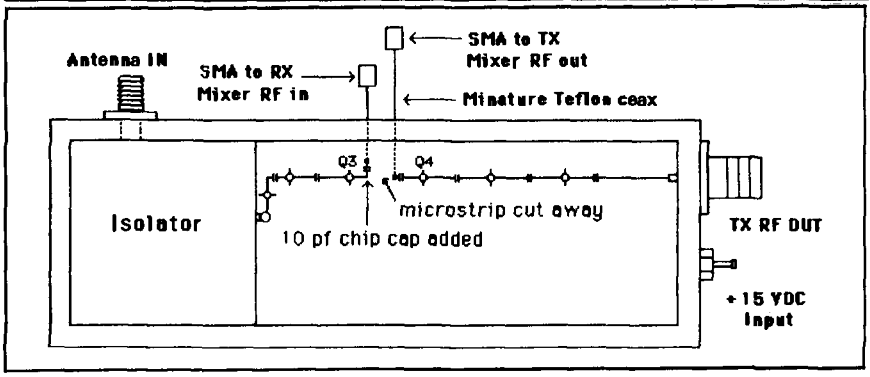
The greater than 50-dB gain LNA is modified again to make two separate three-stage amplifiers. The amplifier I use is the Amplica model ACD 305331 (90 degree) LNA. The 305331 LNA has two GaAsFET stages followed by four bipolar stages and a filter. **Figure 2** shows the "split-in-half" LNA. The transmit amplifier portion provides greater than 20-dB gain. There is greater than 30-dB gain and a 2-dB system noise figure in receive mode.

I modified the LNA by wiring two miniature 50-ohm Teflon® coax cables fitted with SMA male connectors into the amplifier between the third (Q3) and fourth (Q4) stages. The two coax cables should be long enough to go from inside the LNA and connect to the receive and transmit mixers in your transverter. Cut away the microstrip at the interstage DC blocking capacitor to create a gap in the line. Solder a 10-pF chip cap to the output line of stage Q3. This becomes the receive amplifier output. The existing DC blocking chip capacitor becomes the input of the transmit amplifier chain.

Open the other compartment of the LNA. Drill two holes and run the miniature coax through the holes into the compartment. Now drill two small holes in the pc board beside each of the two DC blocking capacitors to pass the coax cable center conductors. Solder the center conductors to the blocking chip caps and solder the shield of each cable to the ground plane at the point where the cable goes through the pc board. The shield relieves strain on the cable, so the chip caps don't break. Apply a dab of RTV or silicone bathtub seal where the cables go through the housing to increase the strain relief and moisture proof the LNA.

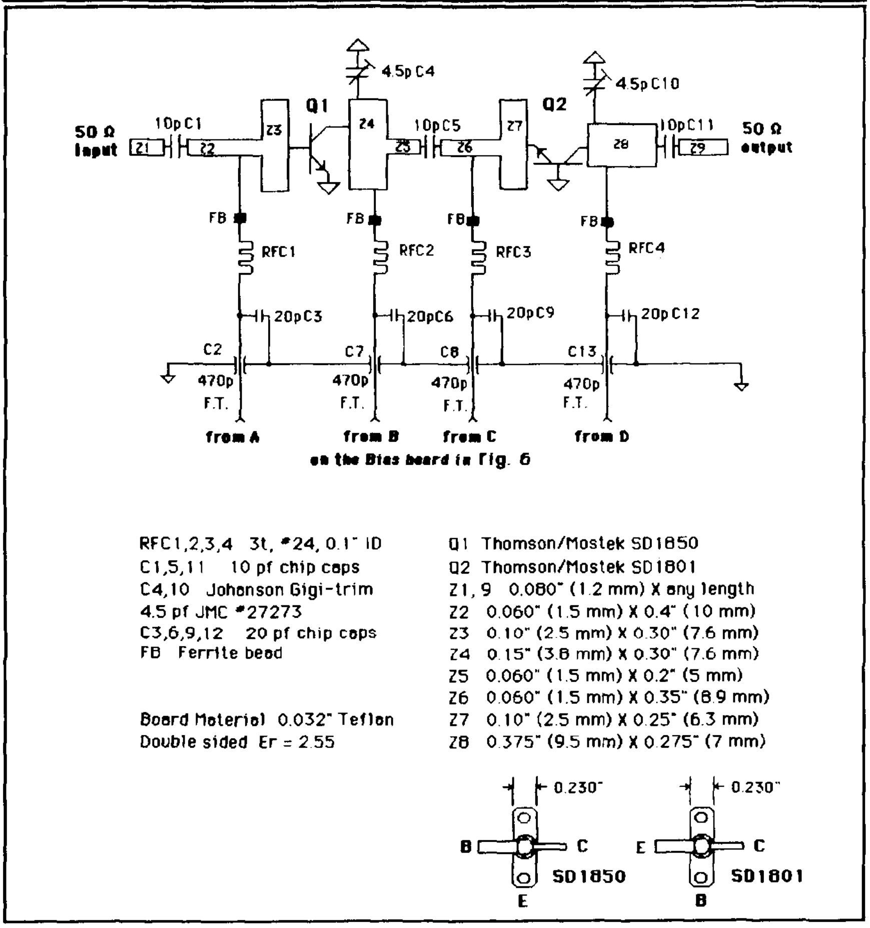
You now have two separate amplifiers. The stability of the receive front end is maintained because the input isolator is still intact. It's okay to leave the

FIGURE 2



A split TVRO LNA showing two separate 3-stage amplifiers.

FIGURE 3



The 2-stage 3456-MHz linear amplifier.

+15 Vdc applied to the LNA; the front end won't oscillate into the open antenna relay during transmit. The LNA has an on-board 7812 voltage regulator, so you can use input voltages from 15 to 28 Vdc.

The receive amplifier output feeds the RF port of the receive mixer. The Mini-

Circuits ZFM-4212 and ZAM-42* are suitable mixers because they are fitted with SMA connectors. The pc board mounted PAM-42 is also a good 3456-MHz mixer. I used the Anzac MD-169 (normally pc board mounted). I enclosed it in a homemade brass housing fitted with SMA connectors.

You can peak the receive amplifier in a noise figure set-up by tweaking the miniature trimmers mounted throughout the LNA. Gain can be maximized at 3456 MHz.

Another application for a split LNA in a transverter involves using one half to amplify the very low output of a 3312-MHz schottky diode multiplier for the local oscillator, and the other half to amplify the transmit mixer SSB output. Try using a second modified 50-dB gain TVRO LNA for the receive amplifier. This approach worked very well for me.

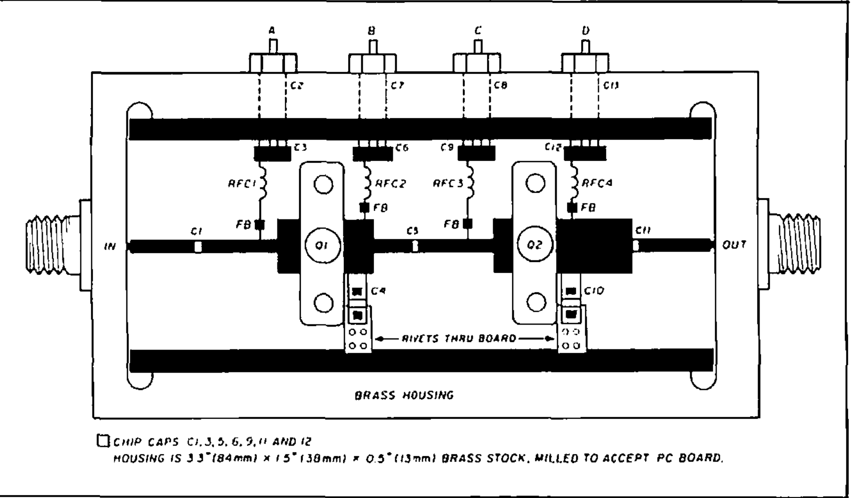
Transmitter stages

You can use the same type of mixer for the transmitter as you did for the receiver. I used the MD-169. The output of the transmit mixer (usually −10 dBm or so) is amplified by the second half of the split LNA, which provides +10 dBm (10 mW) output. The three bipolar stages and filter provide an excellent linear amplifier for low-level signals.

Two-stage linear amplifier

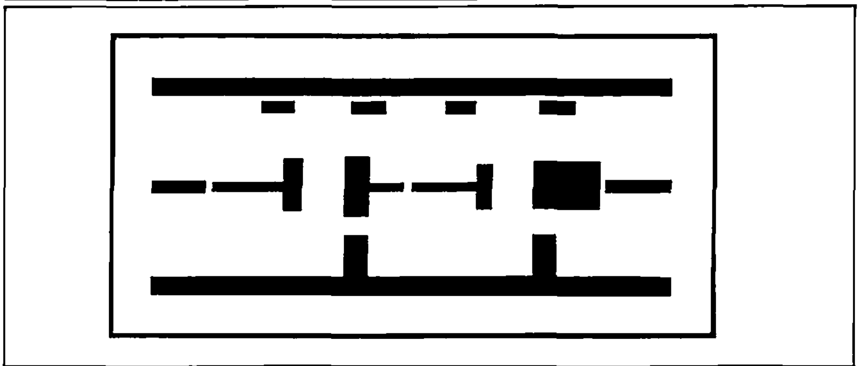
A two-stage linear amplifier, providing 20-dB gain and +27 dBm (500 mW) power output at 1-dB compression, follows the modified TVRO amplifier. The amplifier is shown in **fig. 3**. It was built into one enclosure to eliminate two SMA connectors, and to reduce its overall size. The amplifier is built on 1/32″ Teflon double-sided pc board (Er = 2.55), using microstrip matching networks (see **figs. 4** and **5**). Although the two stages are etched on one pc board and housed in the same enclosure, you can build two separate amplifiers. The DC blocking capacitor (C5) is mounted in a 50-ohm line; the two stages could be separated at this point. Use DC blocking capacitors on the input and output of both stages.

FIGURE 4



Component placement of the 2-stage 3456-MHz amplifier. All components mount on the trace side of the pc board.

FIGURE 5



Full scale artwork for 2-stage amplifier on 1/32″ Teflon® double-sided pc board. Er = 2.55. Opposite side (ground plane) is unetched.

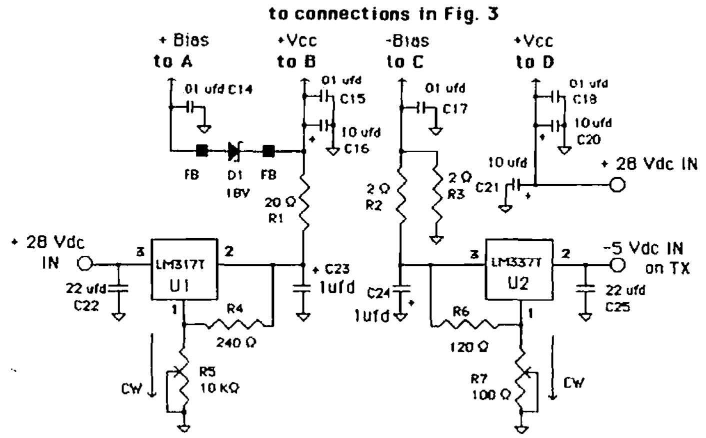
Make all DC and RF grounds low inductance paths through to the ground plane side of the Teflon pc board. Do this by putting multiple rivets through to the ground side. Another method is to cut small slits into the board with an Xacto® knife, and insert and solder strips of copper foil on both sides.

All the amplifiers I build for 1296 MHz and up are constructed from milled-out brass housings. I solder the Teflon pc board into the brass enclosure, and mill two slots in the brass housing to accomodate the flanges of the two transistors. The bypass capacitors and tuning trimmers are mounted on the pc board close to the board edges. This allows direct connection to the brass housing and provides good DC and RF grounding. Holes drilled in the brass box enable you to externally tune the unit with a plastic tuning tool.

The input and output connectors of an amplifier should also be soldered to the ground plane side of the pc board. In my amplifier, I attached the two SMA connectors to the brass box with 2-56 screws and then soldered them permanently. I performed this step on a hot plate when I soldered the pc board in place. You could also solder the connectors on the ends of the pc board in a "launcher" configuration with the center pins of the connectors mounted and soldered parallel to the microstrip.

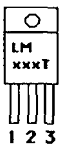
*Mini-Circuits, P.O. Box 166, Brooklyn, New York 11235, (718) 934-4500.

FIGURE 6



Resistors are 1/4 watt except where noted

C16,20,21 10 ufd/35 Vdc electrolytic
C23,24 1 ufd/35 Vdc Tantalum
D1 1N5248B 18 V/500mw zener diode
R1 20 Ω 1/2 watt
R2,3 2 Ω 1/2 watt
R5 10 KΩ minature pc mount pot
R7 100 Ω minature pc mount pot
U1 LM317T Positive regulator
U2 LM337T Negative regulator
FB Ferrite beads



LM317T
1-adjust
2-Vout
3-Vin

LM337T
1-adjust
2-Vin
3-Vout

Bias sources for the 2-stage 3456 MHz linear amplifier. Both regulators are mounted on a heatsink with mica insulators, shoulder washers, and heatsink compound.

Amplifier biasing

The first amplifier stage (Q1) is a common emitter Thomson SD 1850 transistor,* operated as a Class A amplifier. The SD 1850 can be used as a 150-mW Class A linear amplifier from 432 to 3456 MHz. Q1 uses standard zener diode biasing. The second stage (Q2) is a Thomson SD 1801 transistor (a 1 to 2 watt/1 to 3 GHz CW transistor). Q2 is a common base transistor (operating Class AB), and requires a negative voltage for bias in addition to the 28-Vdc collector supply.

I have forward biased many common base devices in the past — many are being used on 1296 and 2304 MHz. In most cases linearity is as good as with a common emitter amplifier. Because microwave power output is at a premium, Amateurs running common base linear amplifiers usually run them closer to power saturation (P_{sat}), rather than in the linear region. This is why the amplifier may sound slightly rough. Other than a few local SSB ragchews, most communications on 2304 and 3456 MHz are on CW.

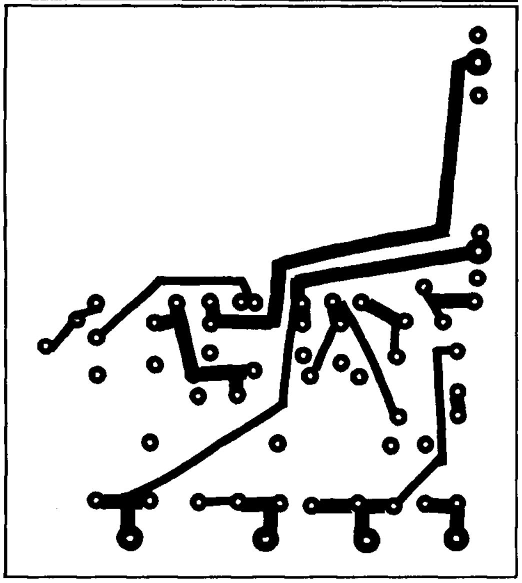
Low-power devices like the 1-watt SD 1801 are easy to bias linearly. Higher power devices like an SD 1597 transistor** require a little more care and a higher current bias source. A common base linear amplifier requires mainly that the bias source be of very low impedance. This is true for the −5 Vdc supply, as well as the associated components of the LM337T regulator. Use an LM337K for higher power common base amplifiers. The regulator in a TO-3 style case is capable of higher power dissipation.

The two bias sources in **fig. 6** were made on an etched G-10 double-sided pc board (shown in the **figs. 7** and **8**). All

*SGS-Thomson Microelectronics, Commerce Drive, Montgomeryville, Pennsylvania 18936, (215) 362-8500. All Thomson transistors are available through: RF Gain, Ltd., 100 Merrick Road, Rockville Centre, New York 11570, (516) 536-8868 and (800) 646-2322.

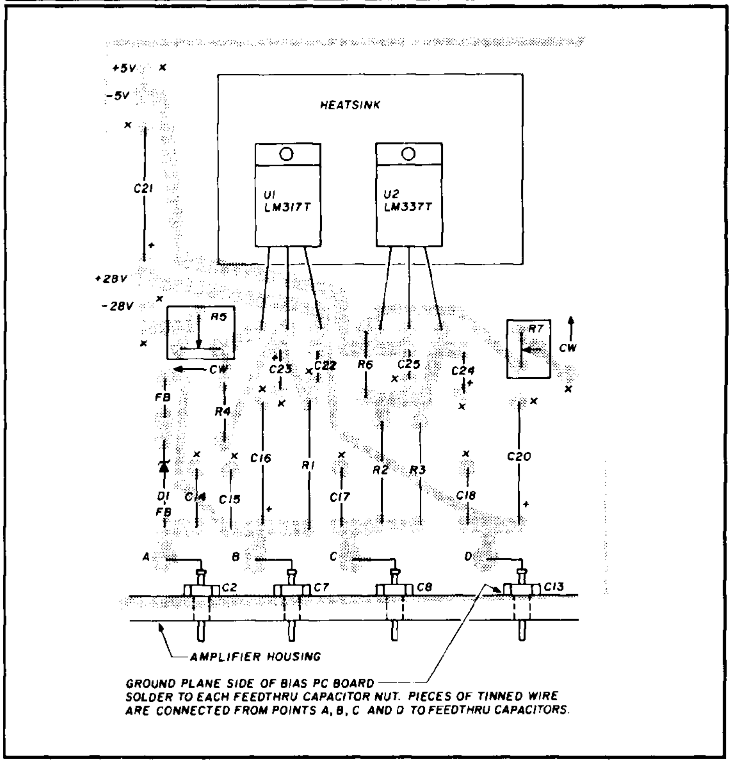
**The SD 1597 is a Thomson 25 watt/1296 MHz transistor for Amateur applications.

FIGURE 7



Full-scale artwork of bias board. Etched side shown. Opposite side is the ground plane and is unetched. Board material is 1/16" (1.6 mm) G-10 double sided.

FIGURE 8



Component placement on the bias board, showing x-ray view of the traces. Parts are mounted on the ground plane side of the pc board, which is unetched. Clear all nonground holes on this side of the board. Solder all grounds on both sides of the board of points "x".

non-ground holes must be "cleared" on the unetched side to prevent component shorting. Begin by drilling the non-ground holes. Remove the copper by counterboring the holes with an oversized bit. Set the depth of the hole to about half the pc board thickness. Drill the ground holes last to prevent confusion about which holes get cleared. Solder components or wiring connected to ground on both sides of the board, as indicated by an "x" in **fig. 8**.

Solder the ground plane side of the pc board directly to the ground posts of feedthrough capacitors C2, C7, C8, and C13 as shown in **fig. 8**. Do this so that the bypass capacitors C14, C15, C16, C17, C18, and C20 will be close to the amplifier (where they will bypass RF most effectively). Use small-gauge tinned wire to connect the bias board to the feedthrough capacitors.

Two power-supply voltages (+28 Vdc and −5 Vdc) are supplied to the board. You can also build a power supply that provides all the positive voltages for a complete transverter (including this bias board).[4] An LM317T (U1) supplies a variable collector voltage for Q1. Adjust the collector voltage without power input (P_{in}), until the 18-Vdc zener diode conducts and biases on Q1. Set the optimum current while tuning the amplifier for power output.

I used an LM337T (U2) as the negative bias source for the output stage (Q2). The output voltage of U2 is halved by voltage divider R2-R3, because 1.2 Vdc is about as low as a three-terminal regulator will go. Note that the −5 Vdc supply must have a floating negative terminal. Peak the idling current while tuning for power output. The −5 Vdc is applied to the amplifier bias board during transmit only. This minimizes heating and possible oscillations into the open antenna relay during receive.

If maximum rather than linear power output (for a rover rig, for example) is a requirement, you could operate the second stage Class C with greater than 1-watt power output. This would eliminate the negative power supply (possibly a 6-volt Gel cell or lantern battery). You'd ground the emitter of Q2 by connecting RFC2 to ground. The microstrip dimensions would stay the same and the stage would be tuned up in the same manner as a linear one.

Tune-up

While I was tuning my amplifier, the two piston trimmer capacitors peaked at minimum capacitance. To bring the trimmers into range, I had to trim off some of the microstrip capacitors with an Xacto knife. I'd used the microstrip dimensions for some single amplifiers that I designed and built earlier. Not going out to 50-ohm connectors interstage produced slightly different impedance matching. Other than this, the amplifier came right up to power and gain expectations. The artwork in **fig. 5** reflects the microstrip dimension changes.

To tune this amplifier and most of others I've built, I used the following equipment: a Wavetek 2005 RF generator, HP435B power meters, and an HP spectrum analyzer (part of an RF test

station at Thomson). You'll need an RF generator and a "real" power meter to check linearity. Do this by changing the P_{in} in 1-dB steps, while looking for the same change in the output. Use the spectrum analyzer to check gain and linearity. Also look for spurious responses.

Now, set the quiescent current (idling current without power input). Attach a 50-ohm load to both the input and output connectors. Adjust both bias adjust pots (R5 and R7) for minimum voltage as measured on the output of U1 and U2. Do this before making connections to the amplifier, to prevent transistor damage. Adjust the Q1 collector current to 80mA with a current meter connected in series with the 20-ohm resistor (R1). Next, adjust the collector current of Q2 to 50 mA with a current meter in series with the collector supply feedthrough capacitor (C13).

Apply 5 mW of 3456-MHz RF to the amplifier input, with a power meter and spectrum analyzer attached to the output. Adjust the two trimmers (while looking at the analyzer and power meter) for maximum output.

The two-stage amplifier will produce maximum power output with 10 to 12 mW of drive. You can readjust the idling current on each stage slightly, under power output conditions for either maximum gain or maximum power output. It's possible to adjust the idling current of Q1 for 80 to 110 mA, and for Q2 up to 65 mA, for proper operation. The total current at 28 Vdc will be 200 to 250 mA when the two-stage amplifier is running at maximum power output.

My two-stage amplifier performed as follows:

Power output at 1 dBc +27.6 dBm (580 mW)/Gain = 19.8 dB

P_{sat} +29.3 dBm (850 mW)/Gain = 18.9 dB

Local oscillator

The local oscillator is probably the most important part of a transverter. It sets the transverter's frequency stability. The i-f frequency is usually very stable and accurate, because it's almost always a commercially made transceiver. Of course, all we're really interested in is the short-term stability. The actual frequency operated on at 3456 MHz can vary many kHz over normal temperature ranges. If you need the exact frequency (i.e., for schedules), use a frequency counter. If a 3.5-GHz counter is unavailable, measure a lower frequency stage of the local oscillator chain on a UHF counter. The 3312-MHz local oscillator frequency will give the 3456-MHz transmit/receive frequency.

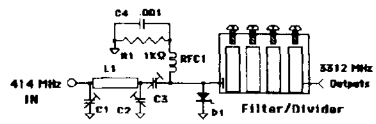
The local oscillator chain in my transverter starts out with a surplus 400-MHz telemetry transmitter strip, which uses a temperature-compensated crystal oscillator. You can find surplus crystal-controlled strips at flea markets; they make stable microwave local oscillator sources.

Step recovery diode multiplier

The 400-MHz module (crystalled up for 414 MHz) drives a X8 step recovery diode (SRD) multiplier (**fig. 9**). The multiplier functions as follows: A pi-network input circuit is used between the 414-MHz module and the SRD, to provide some impedance matching into the diode at 414 MHz. The output of the pi-network (C3) connects directly to the input of the SRD holder. The SRD provides a comb output, consisting of many harmonics of the 414-MHz driving signal. The RF is coupled into the 4-pole comb filter, which filters out the wanted signal (3312 MHz). Dual SMA connectors on the filter output provide the local oscillator signal to both mixers in the transverter.

Most SRDs are packaged without wire leads and require special clamp-type holders for mounting and heat sinking. You can make a brass housing to hold the SRD and provide output coupling into the 4-pole comb filter that follows. Figure **10** shows the SRD holder. Clamp the step recovery diode between part no. 4 (the RF input/output connection) and part no. 6 (a 1/4-20 brass set screw). Use a dab of heat sink compound where the SRD mounts into part no. 6; this aids thermal conduction to the main housing. I made the brass diode holder on a milling machine to fit into the input end of the comb filter. You can make a functional unit with ordinary hand tools.

FIGURE 9



L1 0.2" (5 mm) X 1.25" (32 mm) brass strip
C1,2,3 10pf Johanson trimmer JMC #5200
C4 .001 ufd disc
R1 ≈ 1 KΩ (adjust for performance)
D1 HP 5082-0320 step recovery diode
or HP 5082-0800
or M/A-Comm MA 44608-1
or TRW A45365
or Thomson DH252 or DH256
RFC1 12t, #24, 1/8" (3mm) ID

X8 SRD frequency multiplier and filter.

Depending on the SRD, you can make the 1/4-20 brass set screw (part no. 6) with the appropriate mounting hole. Some SRDs have 3-48 UNC threaded posts that would screw into part no. 6. You could use a glass-packaged SRD by making a Teflon spacer with the glass diode mounted in the center. Fold the wire leads over at both ends and clamp the Teflon spacer into the diode holder.

Attach the SRD holder to the comb filter as in **fig. 11**. It's possible to use an interdigital filter, but a comb filter is easier to mount and tune up because the tuners are on one side.[1,2] A comb filter uses the same dimensions as an interdigital type, but is configured with all the tuning elements on the same side. I used all brass construction. The end walls are 1/4" thick brass stock. Drill holes for the four filter poles, and on the opposite side for the four tuning screws. Solder two SMA connectors to the sheet brass covers. Attach the two covers with 2-56 × 3/16" screws to hold the filter together while soldering all joints on a hot plate.

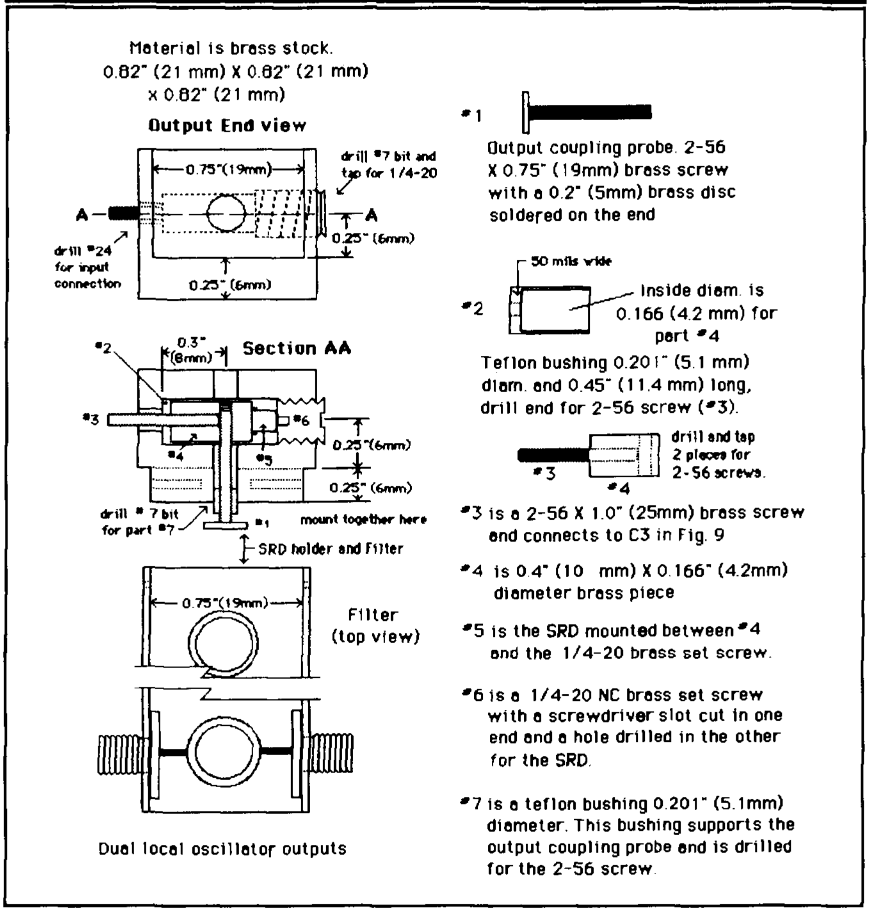
After you've built the filter, attach the SRD holder to it with 2-56 × 3/16" screws. Use a small piece of sheet brass as a mounting platform for the pi-network input circuitry. Attach this assembly to the filter so the SRD input connection (part no. 3) is in close proximity to the trimmer capacitor (C3) of the input circuitry.

Apply the 414-MHz RF to the SRD/filter assembly. Adjust the input network and the filter for maximum power output with a power meter attached on one output port, and a 50-ohm load and spectrum analyzer on the other. Use a spectrum analyzer during tune-up to ensure a clean local oscillator output. Adjust the output coupling probe by threading it in or out of part no. 4. First loosen part no. 3, then tighten it up after the output coupling is optimized. You'll need to adjust the 414-MHz drive for proper output at 3312 MHz (5 to 10 mW at each output connector). The two outputs will be within 1 dB of each other — more than sufficient to properly supply a local oscillator signal to the two transverter mixers. You can change the 414-MHz drive using an LM317T voltage regulator which supplies an adjustable collector voltage to the 414-MHz output stages. In my transverter, power input at 414 MHz was 500 to 600 mW. I made no attempt at optimum input/output matching of the SRD; power at UHF is easy to come by.[5,6]

I provided two outputs on the comb filter instead of using a 3-GHz power divider to split the local oscillator for the two mixers (see **fig. 11**). This is a very simple power divider and you can use it on any comb or interdigital-type filter. You can take two different levels off the filter (for use in a duplex system) if one output uses capacitive coupling. For example, the center pin of an SMA connector provides coupling ≈ 15 dB down from a normally connected output.

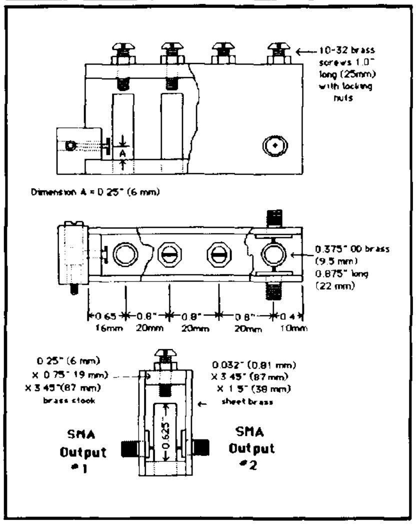
There are a number of combinations for the local oscillator chain. In addition to what's shown in the block diagram, you could also generate 3312 MHz using a 1-GHz local oscillator strip (crystalled for 1104 MHz) driving an active tripler to 3312 MHz. There are a few sources for stable crystal-controlled 1-GHz local oscillator chains.*

FIGURE 10



3466-MHz SRD holder and output coupling detail.

FIGURE 11



The SRD/Filter/Power divider assembly. At top, the SRD holder is shown mounted to the 4-pole filter. The middle is a cut-away view showing the position of the SRD output probe and dual local-oscillator outputs. The bottom is the end view filter/power divider. Connector input-output taps are 0.25″ (6 mm) from the cold end.

Active frequency multiplier

Figure 12 shows the × 3 to 3312 MHz multiplier. The active device is an SD 1801 transistor (Q1). The multiplier is built on 1/32″ Teflon double-sided pc board (Er = 2.55) and mounted in a brass carrier (shown in **fig. 13**). The multiplier is connected to a five-section interdigital filter.[1,2] I used an SMA connector on the input instead of the SRD holder. The input connector is tapped at 0.25″ from the cold end of the input pole.

The multiplier and filter are connected in the transverter with a small piece of UT-141 semi-rigid coax. The exact length of the cable seems to have an effect on the performance of the multiplier. Try different lengths of intercon-

*Down East Microwave, Box 2310, RR #1, Troy, Maine 04987, (207)948-3741. (W3HQT sells the LMW Electronics, model ULO, Universal Local Oscillator kit.) SSB Electronics, 152-MHz Local oscillator chain for their 2304 MHz transverter, crystalled and retuned to 1104 MHz.

necting cable to provide the best match into the filter. The multiplier and filter are effectively one stage and are tuned as such. Again, a power meter is attached to one output, and a 50-ohm load and spectrum analyzer to the other. After tuning the filter for maximum power output at 3312 MHz, you can adjust the 1104-MHz drive level to provide the proper level outputs for the two mixers.

Here's how the multiplier operates. The input of Q1 is tuned to 1104 MHz (or 1152 MHz in a 3456-MHz beacon transmitter). The output is tuned to 3312 MHz (or 3456 MHz). An interdigital filter removes the fundamental and second harmonic frequencies and also provides two outputs for the two transverter mixers. The typical performance of the tripler and filter with one output is 30-mW power input at 1104 MHz (or 1152), which produces 40 to 60 mW output. P_{in} of 50 mW produces greater than 100 mW. When running the multiplier on 15 Vdc, I've seen +23 dBm (200 mW) out of one of these units. You could use this for a beacon transmitter. The 3312-MHz (3456 MHz) outputs are very clean; all unwanted harmonics are down greater than 45 dB and all non-harmonically related signals are down greater than 60 dB.

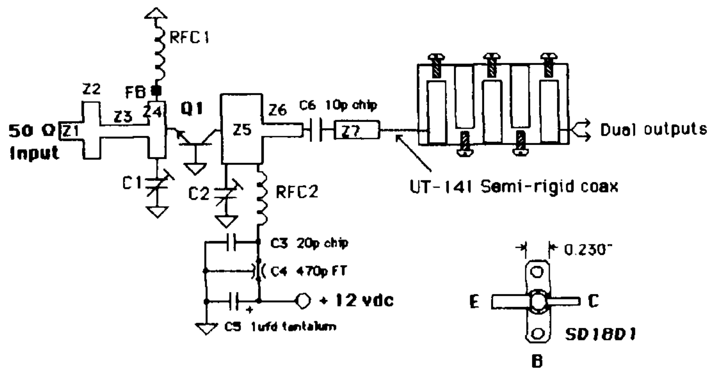
I-F and DC switching

It's necessary to have some means of switching the i-f transmit and receive lines when connecting the 2-meter transceiver to the 3456-MHz transverter. You'll also need a keying circuit to control the transmit/receive of the transverter. This requires one of two different hookups — depending on whether the 2-meter i-f will be a transceiver or another transverter (an MMT-144/28, for example*).

Two-meter transverter as an i-f

Separate receive and transmit connectors are available on the MMT-144 transverter. The i-f output of the receive mixer is connected to the 144-MHz receive port on the 2-meter transverter. On the transmitter side, you must insert an attenuator between the transmit output (nominally 10 watts) of the 2-meter i-f and the 3456-MHz transmit mixer (see **fig. 14**). Adjust the i-f drive level to the

FIGURE 12

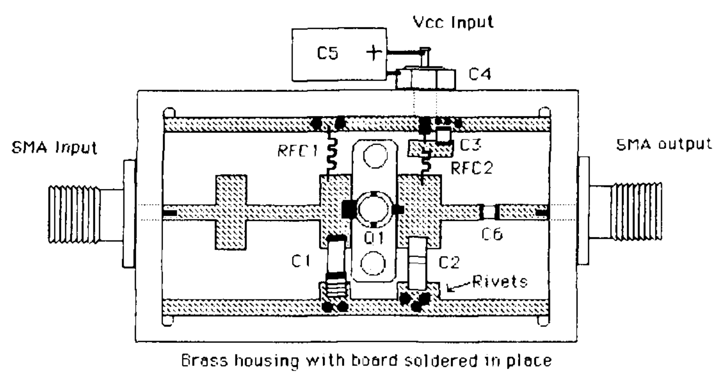


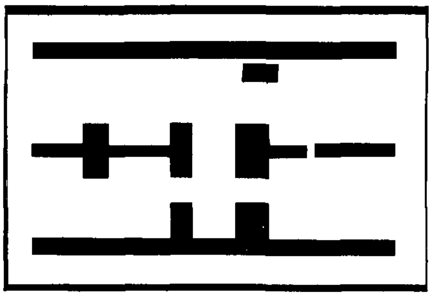
Board material is 0.032" Teflon double-sided
Er = 2.55

C1 3.5 pf Johanson piston trimmer, JMC #5801 or 5802	Q1 Thomson/Mostek SD1801
C2 4.5 pf Johanson Gigi-trim cap, JMC #27273	Z1,7 0.080" (2 mm) X any length 50Ω line
RFC1 6t, #26, 0.1" (2.5 mm) ID	Z2 0.150" (3.8 mm) X 0.30" (7.6 mm)
RFC2 3t, #24, 0.1" (2.5 mm) ID	Z3 0.060" (1.5 mm) X 0.35" (9 mm)
FB Ferrite bead	Z4 0.150" (3.8 mm) X 0.30" (7.6 mm)
	Z5 0.200" (5.0 mm) X 0.30" (7.6 mm)
	Z6 0.060" (1.5 mm) X 0.20" (5.0 mm)

X3 Multiplier to 3312 or 3456 MHz with a 5-section interdigital filter on the output.

FIGURE 13





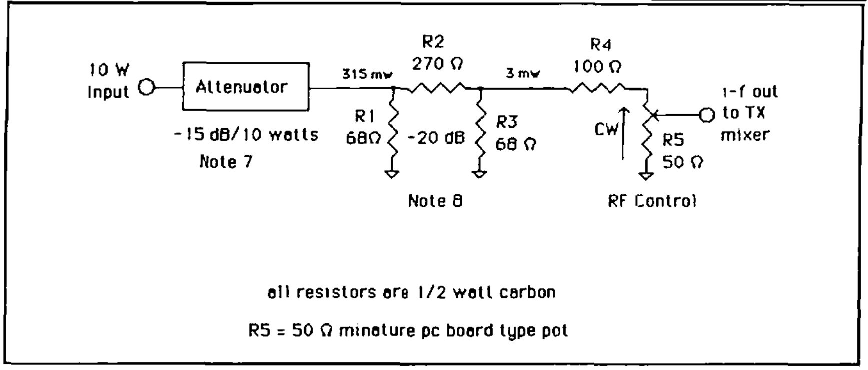
Parts placement on the X3 multiplier and full-scale artwork below. Trace side shown. Opposite side is unetched.

*Microwave Modules Ltd., Liverpool, England, makes a complete line of VHF/UHF transverters.

154

155

FIGURE 14



I-f attenuator and adjustable RF control.

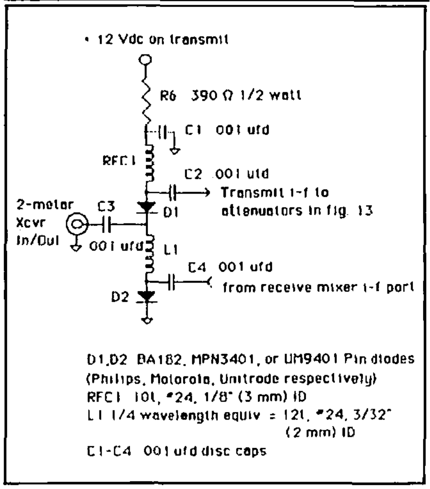
transmit mixer as follows: Turn the RF control (R5) CCW (maximum attenuation). Attach a power meter to the output of the 3456 transverter. Put the 3456-MHz transverter into the transmit mode and apply the 10 watts of drive. Adjust the RF control (R5) for a maximum power output at 3456 MHz. Reduce the 2-meter RF; it should show a decrease in the 3456-MHz output. If there's no reduction in power output, the mixer is being overdriven and you must insert additional attenuation in front of the RF control.

It's important that the i-f radio be operated at its normal output level, and not with the gain or CW control turned down. The RF control in the transverter is adjusted to match the i-f level, not vice versa. This ensures that the transverter will never be overdriven, even when the i-f radio's gain controls are adjusted improperly. The procedure is correct for any transverter system.

Two-meter transceiver for the i-f

Figure 15 shows a Pin diode RF switch that provides switching for the 2-meter i-f during transmit and receive. The i-f transceiver is connected to the Pin diode switch; this gives two separate ports similar to the outputs of the 2-meter transverter described earlier. The RF attenuators* and RF control are also used in this installation. The i-f drive adjustment is the same as if you were using a transverter. Don't make changes in the RF drive with the 2-meter transceiver in the "low power" position or you'll be asking for trouble.

FIGURE 15



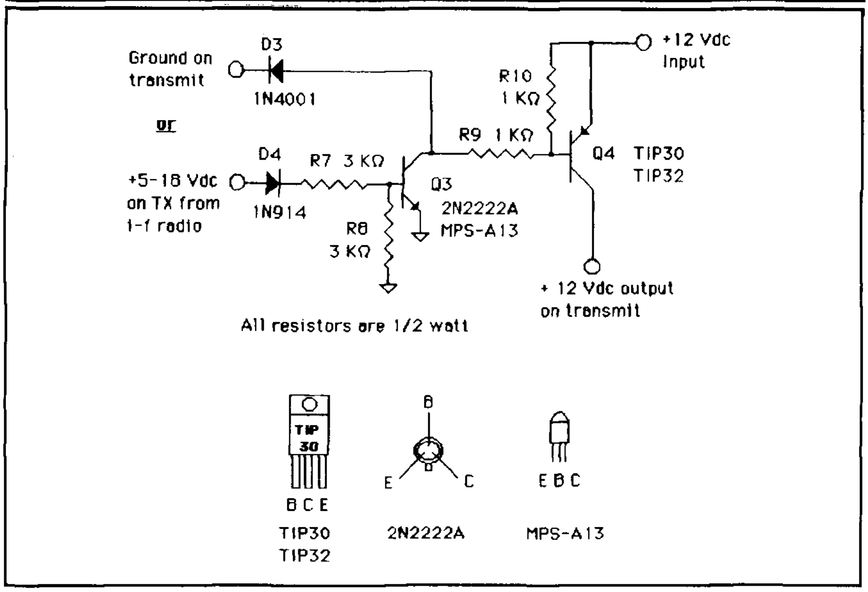
Pin diode RF switch.

DC control circuits

Control the 3456-MHz transverter with "hard keying." Use RF sensing *only* as a last resort. Hard keying is simple. Take a transmit voltage off the i-f radio — either via an accessory jack, or by going inside and soldering a wire to a resistor lead. You just need a voltage between 5 and 18 volts on transmit at a few milliamps of current. Check your radio's schematic to determine where to look with a voltmeter. **Figure 16** shows a DC switching circuit that provides 12 volts on transmit to control the Pin diode switch in fig. 15. The 12 volts will also key your 3456-MHz transverter control circuits and power supply[4].

*Microwave Modules RF Attenuator Models: MMR 3/25 = 3dB/25 watt, MMR 7/3 = 7dB/3 watt, MMR 15/10 = 15dB/10 watt

FIGURE 16



DC switching circuit, controlled by the i-f transceiver in the transmit mode.

Antenna relays

You can use antenna change-over relays manufactured by Transco Products, Inc. (and other manufacturers) at 3456 MHz. Look for surplus relays at flea markets. Some have specially made connectors designed for the military. Unfortunately, matching connectors usually aren't available. I use a Transco latching-type relay, P/N 82132-909C. It cost me $5.00 at a flea market. The connectors resembled an SMA female jack, but had male center pins. I removed the threaded-in connectors and installed female SMA connectors. Insertion loss, measured at 3456 MHz, is 0.1 dB; isolation is greater than 60 dB. Surplus relays manufactured by Electronic Specialty Company are usually good for 3456 and 5760 MHz.

Conclusion

The design for this transverter is relatively simple. A few basic components are all you need to build a "bare-bones" unit for mountaintop work. Besides the local oscillator, two mixers and the "split" TVRO LNA will get you on the air. You can use manual transmit-receive change-over (moving a coax cable between RF ports) with good results, as speed isn't usually a requirement. Microwatt transmitters and diode receivers are adequate for most line-of-sight communications. You can always add fancy switching and higher power output later.

You can use some of the component designs for other microwave projects. For example, the SRD multiplier is suitable for a beacon transmitter. The HP 5082-0320 diode is capable of much more power output at 3456 MHz than is used in this transverter. It's possible to find other 1 to 5-watt SRDs that will fit into the same holder. Try using the active multiplier for the output or driver of a beacon transmitter. Adjusting the collector voltage and RF power input for maximum yields 200 to 300-mW power output.

This transverter is one of many possible designs.* Microwave enthusiasts in other parts of the country are using surplus phase-locked sources for their local oscillators. TVRO mixers are also in service. GaAsFETS and surplus tube-type amplifiers are being used for the transmitters. There's also an assortment of TVRO, surplus, and homebrew GaAsFET receivers at work.

The majority of activity on this band comes from mountain-topping stations and local QSOs. Many stations will soon be on the 3.4-GHz band, and QSOs similar to 2304 MHz will be commonplace. Besides the parabolic antennas normally used on the microwave bands, the loop Yagi is becoming a popular antenna for 3456 MHz.**

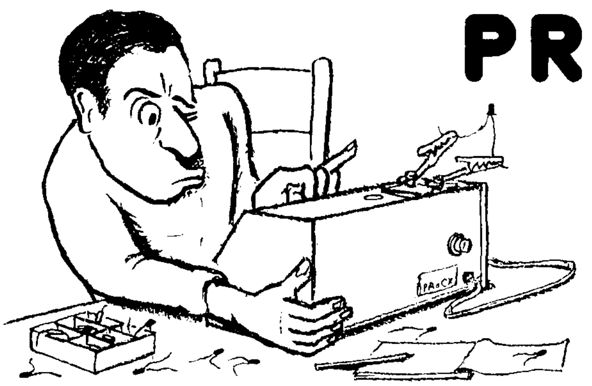
*The ARRL Handbook

**Down East Microwave, Box 2310, RR #1, Troy, Maine 04987, (207) 948-3741 sells loop Yagi antennas for all bands 902-3456 MHz.

References

1. Bob Atkins, KA1GT, "The New Frontier," *QST*, May 1984, page 77.
2. R. Fisher, W2CQH, "Interdigital Filters," *QST*, January 1974.
3. Bob Atkins, KA1GT, "The New Frontier," *QST*, August 1987, page 59.
4. Dave Mascaro, WA3JUF, "Transverter Switching Display and Universal Transverter Power Supply," *QEX*, August 1987, page 8.
5. Hewlett-Packard Application Notes no. 913 and 920, May 1967.
6. R.E. Winkelman and E.G. Cristal, *Microwaves and RF*, September 1970, page 34.

Article I **HAM RADIO**



PRACTICALLY SPEAKING

Joe Carr, K4IPV

Parts for antenna tuners and linears...plus a correction

One of the delights of writing for a magazine like *Ham Radio* is receiving reader mail. Sometimes I get brickbats either for not covering a pet topic, or covering it in a way that someone doesn't like. I also get kudos and congratulations for covering a topic well, or covering one that other magazines seem to overlook. But let me make a mistake, and my mailbox fills up in a hurry — *HR* readers are a sharp lot! Fortunately, most of the "eagle eyes" simply point out the error and let me off the hook easily. Others...well, others...I won't tell you about them, except to state that for some people columnists' mistakes are mortal sins.

One error turns out to be not an error at all, merely an oversimplification. In one column I warned you to be careful of NPO capacitors because they are not really zero temperature coefficient. Most of them are 0 ± 30 ppm. Although I prefer silvered mica capacitors, some of you don't like them because they seem variable with respect to tempco (despite the rating). It turns out that I was right after all, but so were those of you who wrote. The selection of the low tempco capacitor is a lot more complicated than I (or any other Amateur Radio writer) have shown. I am researching the issue, and may write a column about it in the future. If you have information or opinions, write to me at the address at the end of this column.

Tuner/linear parts

Antenna tuners and linear-amplifier RF tuned circuits are popular Amateur Radio construction projects. That old saw, offered by scores of doomsayers, that hams don't build anymore is belied by my mailbag. Many people have written me (more than 60 in response to the spectrum analyzer column) on construction projects. A common question regards the class of parts used for tuners and linear amplifiers. When a schematic shows a variable capacitor, the capacitor could be a screwdriver-adjusted trimmer or a mighty vacuum variable. I'll take a look at a couple of different types of components this month.

Another question I see frequently concerns supply sources. Hamfests are traditional places to find linear/tuner parts, but those events are either drying up or people are asking an arm and a leg for parts. I saw a corroded (really scuzzy) transmitting-type variable capacitor at a hamfest; the owner wanted only $3 less than the price Radiokit was asking for a brand new one! Although hamfest bargains (and reasonable deals) still abound, you might contact some of the vendors shown in **table 1** for mail order purchases, or to locate a dealer who can help you.

TABLE 1

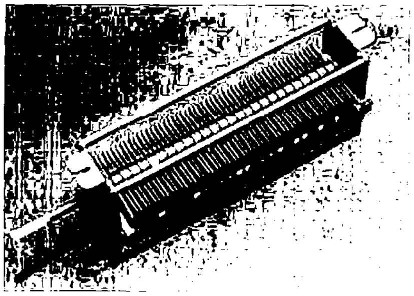
List of suppliers

Radiokit, POB 973, Pelham, New Hampshire 03076, (603) 635-2235
Barker & Williamson, 10 Canal Street, Bristol, Pennsylvania 19007, (215)788-5581
Fair Radio Sales, 1016 East Eureka Street, POB 1105, Lima, Ohio 45802
Nevada Communications, TELECOMMS, 189 London Road, North End, Portsmouth, PO2 9AE, England
Unadilla/Antennas Etc., POB 215 BV, Andover, Massachusetts 01810-0814, (617)475-7831
Van Gorden Engineering, POB 21305, South Euclid, Ohio 44121
SPI-RO Manufacturing, Inc., POB 1538, Hendersonville, North Carolina 28793
Alpha Delta Communications, Inc., POB 571, Centerville, Ohio 45459 (513)435-4772

Let's take a look at the types of parts that are suitable for building antenna-tuning units or the RF output deck of a linear, or class-C, RF power amplifier.

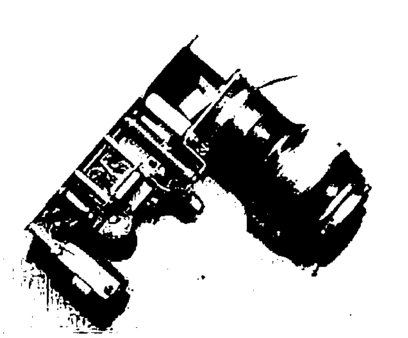
Photos A and **B** show a pair of high-voltage variable capacitors suitable for use in high-power applications. The capacitor in **photo A** is a 250-pF model about 10 inches long, with wide spacing between plates to accommodate the high voltage. In the model shown, the shaft has a nylon end piece

PHOTO A



High-voltage, air-dielectric variable capacitor.

PHOTO B



Motor driven 1000-pF vacuum variable capacitor.

that permits the stator plates to be at high voltage (where necessary) without placing the operator at risk. This particular capacitor (as well as the inductor in **photo C**) is part of the antenna-tuning unit kit offered by Radiokit (see **table 1** for address).

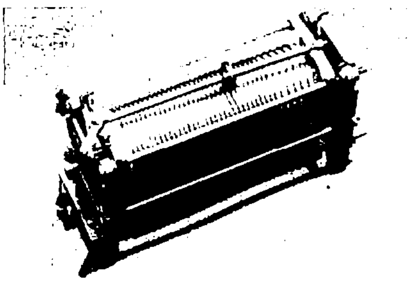
The capacitor in **photo B** is a 1000-pF vacuum variable. This model is surplus, and was obtained from Fair Radio Sales in Lima, Ohio. The surplus capacitor cost considerably less than the new vacuum variables, and a lot less than some hamfest "tailgate specials" I've seen in recent years. In this case, a motor drive mechanism is supplied allowing the user to set the capacitance by applying a +12 Vdc source to the motor control. Microswitches at the limits of travel can be used either to provide warning to the operator that the limit is reached, or automatically turn off the power to the motor and reverse the direction of travel. I plan to use this capacitor in an outdoor (remotely tuned) antenna-tuning unit.

Photos C and **D** show a pair of inductors used for antenna-tuning units. The version in **photo D** is a fixed coil made from B&W 3029 stock. There are three methods for connecting leads to the coil. One is to use an alligator clip. Press down a short section of alternate turns to allow the clip to be attached without shorting adjacent turns. Another is to simply solder a wire to a turn of the coil. Finally, sources like Radiokit sell special coil clips that screw onto the coil stock. Use either a manual attachment or an RF switch to select the required inductance.

The inductor shown in **photo C** is a rotary inductor. This one selects inductances from about 1-28 μH. A rotary shaft on the front end of the coil sets the inductance.

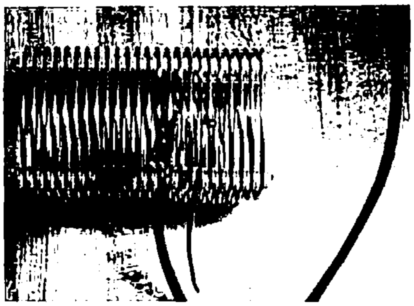
Photo E shows an antenna-tuning unit from Nevada Communications in England. I ordered this instrument through the mail (Nevada can accept most of the major charge cards familiar to United States customers).

PHOTO C



Roller or rotary inductor.

PHOTO D



Fixed inductor made from B&W miniductor stock.

✓ 156

Nevada also sells the individual components. One capacitor (shown on the right) is a 250-pF variable; the other is a dual-section 250-250 pF model. It can be used as either a dual capacitor in a Transmatch circuit, or can be connected in parallel to form a 500-pF unit.

Dummy loads

A dummy load is a substitute antenna for making measurements and tests. In fact, British radio engineers often refer to dummy loads as "artificial aerials." There are several uses for these devices. Radio operators should use dummy loads to tune up on crowded channels, and only then transfer to the live antenna.

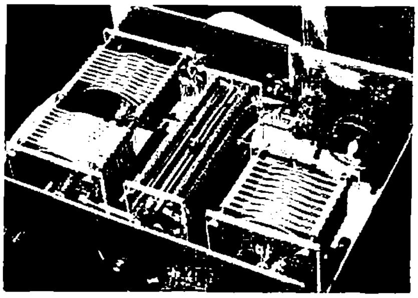
Dummy loads can also be used when troubleshooting antenna systems. Suppose you have a system in which the VSWR is high enough to affect the operation of the transmitter. You can disconnect each successive element and connect the dummy load to its output. If the VSWR goes down to the normal range, then the difficulty is downstream (i.e., towards the antenna). You'll eventually find the bad element (which is usually the antenna itself).

Several commercial dummy loads are shown in **photos F** through **H**. **Photo F** is a Drake DL-1000. This dummy load is usable throughout the HF region, and will handle 1000 watts for short periods. A long, high-power, noninductive resistor element inside the DL-1000 is rated at 50 ohms, and can dissipate 1000 watts for several minutes. If you anticipate longer times or higher powers, apply forced air cooling by adding a blower to one end of the cage.

I modified my DL-1000 by adding a BNC signal sampling jack. Connect this jack internally to either a two-turn loop made of no. 22 insulated hookup wire, or to brass rods positioned alongside the resistor element. It will then pick up a sample of the signal so that it can be viewed on an oscilloscope, or used for other instrumentation purposes. I'll discuss this modification in a future column.

Photo G shows a small collection of my low-power dummy loads. The small gray load in **photo G** is a 5-watt model, and is typically used in Citizen's Band servicing. The resistor is mounted directly on a PL-259 coaxial connector. These loads typically work to about 300 MHz, although many are not really useful over about 150 MHz. I have successfully used it to service a 2-watt, 2-meter handheld. A higher power version of the same type is also shown in **photo G**. This device works to the low VHF region, and dissipates up to 50 watts for short times, even though it is rated at 15-watts continuous power. I have used this dummy load for servicing high-VHF landmobile rigs, VHF-FM marine rigs, and low-VHF landmobile rigs — as well as Amateur Radio rigs.

PHOTO E

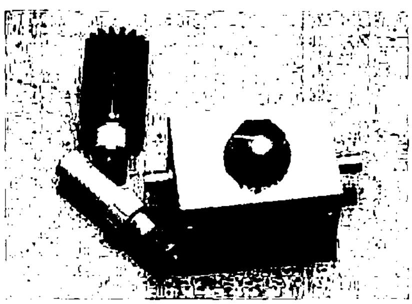


Nevada antenna tuner unit.

PHOTO F

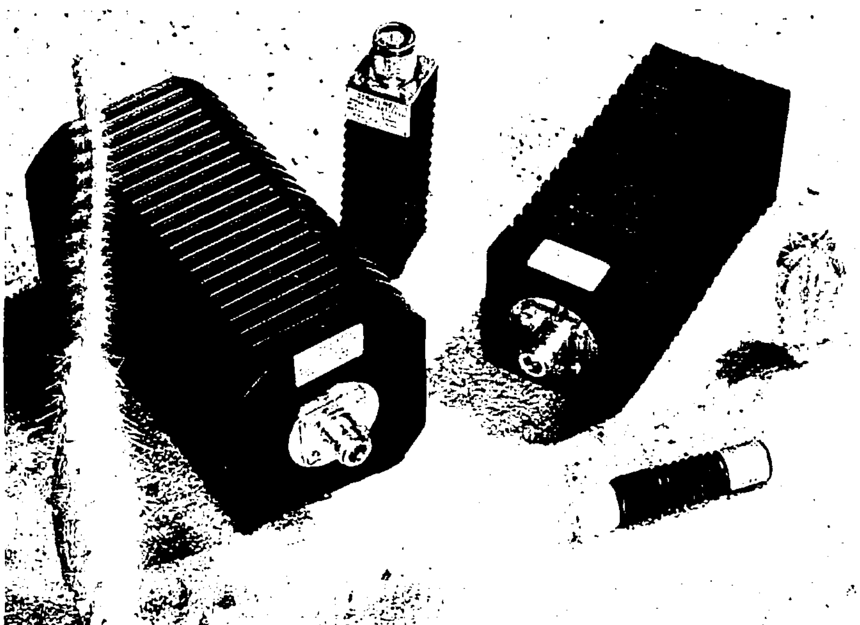
Drake DL-1000 dummy load for HF bands.

PHOTO G



Collection of small dummy loads.

PHOTO H



Commercial dummy loads made by Bird Electronics, Inc.

The load box shown in **photo G** is a homebrew device containing ten different 2-watt, carbon composition, *noninductive resistors*. Also included are a zero-ohm switch position (shorted to ground) and an open position (which requires an external load, or produces an "infinite" impedance). I used this dummy load to produce the photos in a past column on time domain reflectometry methods.

Photo H shows a small collection of 8000-series Termaline® dummy loads produced by Bird Electronics, Inc. These are professional instruments and are rated very conservatively. If you plan to service a lot of equipment or go into business, then it's probably a good idea to buy one or more of them. Even Amateurs with a modest workshop may want one of these professional loads.

I can be reached at POB 1099, Falls Church, Virginia 22041; I'd like to have your comments and suggestions for this column.

Article J **HAM RADIO**

THE WEEKENDER

A simple signal source for 903 MHz

Circuit testing is probably one of the most difficult problems you'll encounter when building equipment for the higher frequency Amateur bands. It's even harder on a new band, because you may have no operational equipment to use as a starting point. I've built a simple reference-signal generator for the 903-MHz band that can be operated without any other RF test equipment. Try using it as the reference point for adjusting antennas and equipment.

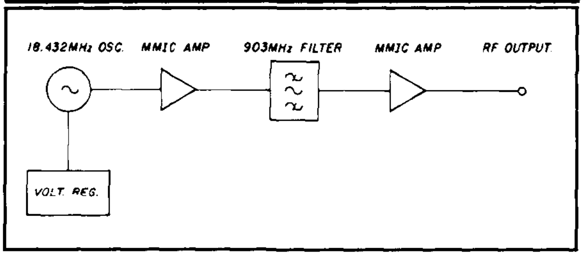
Circuit description

The idea for this test-signal generator came to me while I was looking through a catalog of standard TTL crystal oscillators. These oscillators, intended for use in digital computer equipment, are inexpensive and fairly accurate signal sources. One commonly available oscillator operates at 18.432 MHz and has a convenient 49th harmonic of 903.168 MHz. It's very near to the 903.1-MHz calling frequency — certainly close enough to be useful in testing and tuning equipment for the entire 33-cm band.

Once I realized that this oscillator's harmonic falls on a useful frequency, I started wondering how to use it to build a signal generator. The block diagram in **fig. 1** came to mind. The crystal oscillator's output is amplified and its harmonic level enhanced. A sharp, pretuned filter rejects most of the undesired harmonics and another amplifier increases the level of the 903-MHz signal. It requires no adjustments or external calibration.

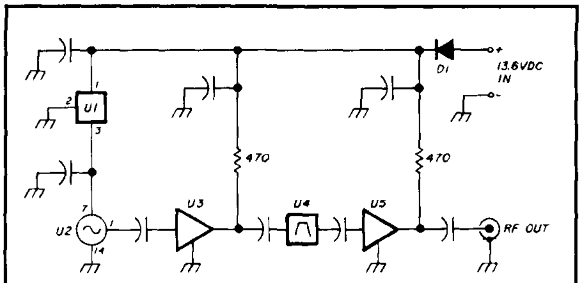
By Jerry Hinshaw, N6JH, 10 Acorn Circle, #101, Towson, Maryland 21204

FIGURE 1



Block diagram of the signal generator.

FIGURE 2



U1 78L05 5-volt integrated circuit voltage regulator 100mA rating.
U2 18.432-MHz TTL crystal oscillator modula (Digi-Key P/N X118).
U3, U5 MMIC amplifier MSA-0104 or MSA-0185 or MAR-01. See text.
U4 903-MHz helical resonator two section (Digi-Key P/N TK3313) or three section (Digi-Key P/N TK3401).
D1 1N4001 or equivalent.
All capacitors 0.01-μF ceramic disc.
All resistors 1/4-watt carbon composition.

Detailed schematic diagram and parts list of the circuit.

The schematic diagram in **fig. 2** shows each of the subsystem "blocks" in detail. The first stage to the left is the oscillator. It needs a 5-volt supply and ground to provide a stable output. This voltage regulator reduces the 13.8-volt supply to 5 volts, and its regulation helps prevent "pushing" (frequency shifts caused by power supply variations).

The stage after the oscillator is an MMIC amplifier; it serves two functions. First, it isolates the oscillator from output impedance changes which would alter the oscillator frequency (a phenomenon sometimes called "pulling"). The MMIC amplifier, with its low reverse gain (S_{12}), acts as a buffer and shields the oscillator from load changes. It also isolates the oscillator from the filter's high VSWR at frequencies outside the passband. Second, the amplifier enhances the oscillator's harmonic output. (After all, it's the 49th harmonic that falls in the desired band — not the fundamental.) Use an amplifier which has a low output compression point for this function, so that it's driven into saturation by the oscillator's signal. When saturated, the amplifier operates nonlinearly and produces more harmonic power (since harmonics are distortion products produced by nonlinear amplification). This MMIC stage has considerable gain from HF to above 1 GHz, covering the fundamental of the oscillator at 18.432,

the desired harmonic at 903.168, and all points in between.

There are a number of silicon MMIC amplifiers which will work well here. As I mentioned before, the main requirement is for gain saturation when driven by the oscillator. I used an Avantek MSA-0104, biased with a resistor to about 15mA collector (output lead) current. Other possible choices are the MSA-0185 (the same device in a smaller plastic package) or the Mini-Circuits MAR-1 (which appears to be the Avantek MSA-0185 device sold under a different label). The slightly higher power Avantek MSA-02 (Mini-Circuits MAR-2) would probably work well enough, although the output level might be a bit lower due to its lower gain. The MSA-06 (MAR-6) would also be a good choice. It's similar in many ways to the MSA-01, except for its lower collector voltage and lower noise figure. The latter is of little merit in this application.

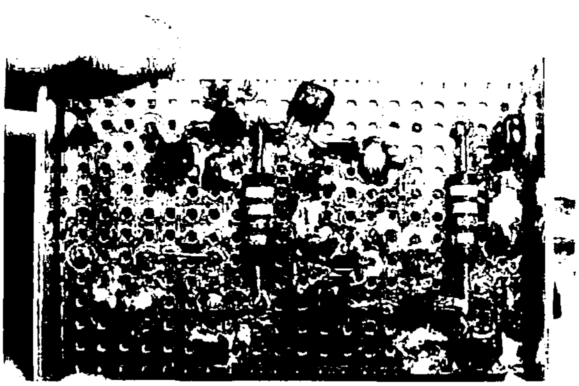
The next stage is the filter. The ideal filter would have no loss at 903 MHz, and infinite loss at all other frequencies. In practice, we want as much rejection as possible. The undesired harmonics are unfortunately close to the desired spectral line, only 18.432 MHz above and below the output at 903.168 MHz. This signal generator's circuit architecture is not ideal for rejection of undesired harmonics because the multiplication order is so high — the price you pay for such simplicity. Still, if the filter can reject the adjacent harmonics (numbers 48 and 50) by 10 to 20 dB relative to the harmonic at 903 MHz, the output will be quite useful.

Commercially available helical resonator filters are a good choice for this application. They are narrowband, have sharp rejection skirts, and low insertion loss at their center frequency. The Toko company manufactures a line of helical resonator filters with two or three resonator sections. Some even come pretuned. Either the two or three- section filter will work, but the three-section one gives a cleaner output spectrum due to its greater attenuation of the adjacent harmonics. The Toko filters available in the 900-MHz region have passband widths of about 10 to 15 MHz, measured at the −3 dB points, and losses of about 4 dB at the center frequency. They are packaged in small metal cans with radial leads at the bottom. You'll need good grounding to make them work, but otherwise they're trouble free.

A second MMIC amplifier after the filter increases the signal level of the 903-MHz line — the strongest harmonic at this point in the circuit. Here the signal level is low, so a high gain MMIC amplifier with a low compression point is again suitable (though for somewhat different reasons than for the stage ahead of the filter). Any one of the MMIC amplifiers mentioned before will work.

In summary, the test-signal generator is a chain consisting of an oscillator followed by a multiplier/amplifier, a narrow filter centered at the output frequency, and an output amplifier. There are only four stages, few components, and no adjustments.

PHOTO A



Details of the prototype's circuit board. The crystal oscillator's four leads are seen at the upper left. The first MMIC amplifier is at the top, and the bandpass filter is near the center. The output MMIC is at lower right.

Construction details

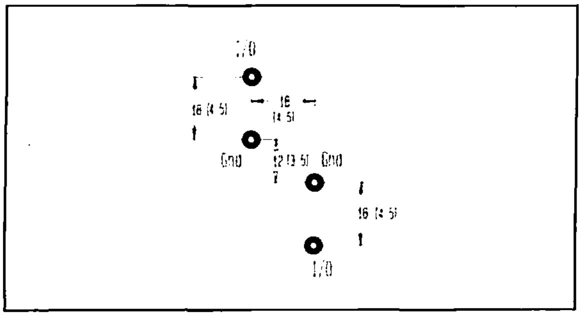
There's little need for a printed circuit board for a simple project like this; the usual Amateur methods work well. I used a copper-clad perfboard for the prototype. The oscillator DIP and the helical filter sit on the unclad side of the board while the smaller RF parts solder directly onto the copper-clad side. You can see many of the construction details in **photo A**.

The crystal oscillator's leads protrude through the holes in the perfboard. Two of the leads (the DC power lead and the RF output) are isolated above ground, so I cleared away the copper with a pad cutter. The other two leads are soldered to the copper foil, which is the ground plane for the circuitry.

Install the MMIC amplifiers by bending their two ground leads flush to the package and soldering them to the copper ground foil, as close as possible to the MMIC package. This gives them low-impedance ground connections. Leave the input and output ribbon leads suspended in the air; they are both short and stiff so no other support is needed. Solder the input and output coupling capacitors and the output bias resistor directly to the MMIC leads. Make the connections as short as practical, as is the practice in the "hot" portions of UHF circuitry. Short leads increase the mechanical strength of the assembly.

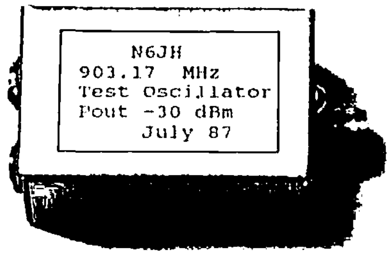
The hardest part is mounting the helical resonator filter, because its leads aren't on the perforated circuit board's 0.1-inch grid pattern. This means that you must drill special holes for at least some of the leads. **Figure 3** shows the pin connections and spacings for

FIGURE 3



Mechanical pin outline drawing of the two-section filter. Dimensions are inches (millimeters).

PHOTO B



External view of the signal generator installed in a small metal box. The RF output is via the BNC connector to the right; DC power connects to the Banana jacks on the left.

the two-section filter. Bend the metal mounting tabs on the filter flat and solder them to the board's copper ground foil.

The test oscillator can easily be built inside a 2″ × 1.5″ × 1.5″ box. A shielded box is preferable. It allows for the cleanest possible output, because only the filtered signal is permitted to exit the box by way of the output connector. **Photo B** shows my version, mounted in the ubiquitous "Bud" box. The output connector is a BNC type. It's a lossy choice at this frequency, but convenient, widely available, and inexpensive. DC power for the circuitry comes in through banana jacks.

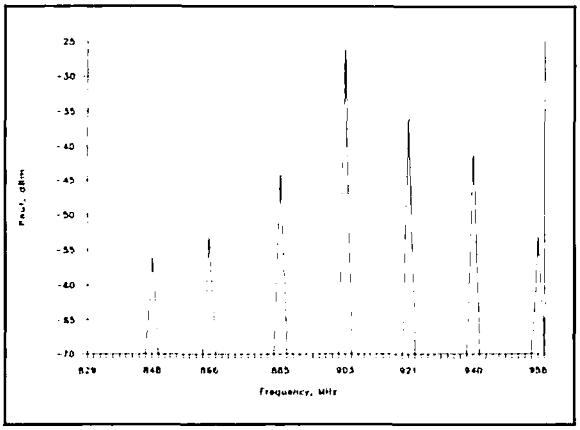
Operation and test results

Once the circuit board is fully assembled (it took me about 90 minutes), it's ready for operation. No tuning is needed, and in fact none is possible. (The helical filters have screw adjustments which could be tuned for better response, but that's probably not a good idea without a spectrum analyzer.) The test oscillator should draw about 100 mA at 13.6 volts. Each of the MMIC amplifiers should have about 4 volts at the output tab, and about 1.6 volts at the input lead. There should be 5 volts at the output of the voltage regulator supplying the oscillator. If all of these voltages are correct and present, the signal generator should be operating.

As soon as I applied DC power, the prototype worked and produced a strong signal at about 903.2 MHz. The audio note was fairly pure — quite pleasingly so for a crystal oscillator that was not designed for low phase noise and multiplied 49 times. (The phase noise of an oscillator is increased during frequency multiplication.)

On a spectrum analyzer, the output signal measures −26 dBm (2.5 μW) at the circuit board. This is not a huge signal by transmitter standards, but plenty large for testing even insensitive receivers. The spectrum appears fairly "clean" and the adjacent harmonic lines

FIGURE 4

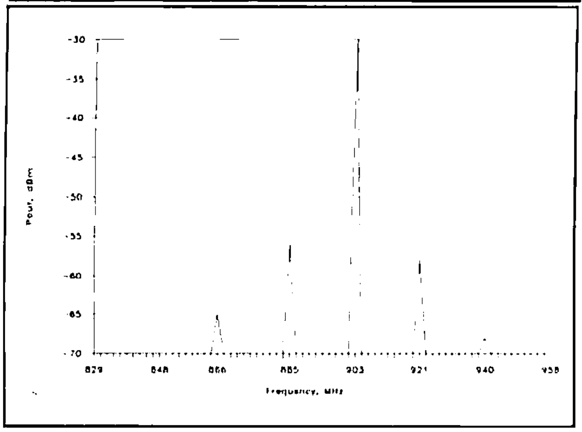


Spectral plot of the test oscillator's output. The main signal at 903.17 MHz is at about −26 dBm; all other harmonics are at least 10 dB below that.

are down more than 10 dB below the desired output. This is acceptable for a tuning indicator, and is good for a crystal reference. A spectrum plot is shown in **fig. 4**. You can see that the adjacent harmonics are rapidly attenuated away from the desired 903 center. All of the harmonics below 800 MHz and above 1 GHz are at least −70 dBm.

When a three-section helical resonator is *used in* place of the two-section model, the results should be even better — as indicated in **fig. 5**. I made the prediction that appears in **fig. 5** from the vendor's test data of filter attenuation of the three-resonator filter. Of course the three-section filter is more expensive, but the output purity is considerably better. The three-section filter is generally a good idea; for antenna testing (where the signal is radiated in space) the better filtering is probably essential. Building the test generator should be no different with the more selective filter, except for the necessary change required in the mechanical layout due to the filter's slightly larger size.

FIGURE 5



Predicted spectral plot for a signal source using a three-section helical resonator in place of the two-section filter used in the prototype.

Summary

This simple project provides a useful tool for aligning filters, amplifiers, and receivers and also for antenna testing. Because it can be built and used without needing alignment, it's a good starting point for work in the 903-MHz band. Use a similar approach with a different crystal oscillator and the proper filter to make a test generator for frequencies from at least 200 MHz up to 1200 MHz. You can assemble a "quick and dirty" version in less than one hour; a carefully constructed version — including packaging — shouldn't take more than three or four hours.

Article K HAM RADIO

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INDIANA: January 7. South Bend Hamfest Swap & Shop, first Saturday after New Year's Day, Century Center downtown on US 33 Oneway North between Trustcorp Bank Building and river. Four lane highways to door from all directions. Tables: $5/5 ft. round; $15/8x2.5 rectangular; $20/8 ft. wall locations. Talk in freq: 52-52, 99-39, 69-09, 34-94, 145.29. K9IXU (219) 233-5307.

WISCONSIN: January 14. 17th annual Midwinter Swapfest sponsored by the West Allis Radio Amateur Club, Waukesha County Exposition Center Forum, Highways J & FT, Waukesha. 8 AM to 3 PM. Admission $2/advance; $3/door. Reserved 4' tables $3.00; at door $4. Free coffee and donuts until 9 AM. Amateur exams. Packet Radio meeting. Send SASE to WARAC Swapfest, POB 1072, Milwaukee, WI 53201

MASSACHUSETTS: January 14. MMRA, Minuteman Repeater Association, Flea Market, Westborough Senior High School. Admission $2. Tables $10/advance; $13/door. Doors open to sellers 8:30 AM. Talk in on MMRA's 146.01/.61 repeater. For tables contact Scott Bullock, KA1CLX 26 Willis Street, Apt 21, Framingham, MA 01701 (508) 872-4961 or Andrew Morrison, N1BHI (508) 481-3878.

LOUISIANA: January 21. SELARC Hamfest, South Eastern LA University Rec. Center. Exams, tables and fun. Wheelchair accessible. Joe Farris, 390 Piney Woods, Ponchatoula, LA 70454. (504) 386-8393.

MICHIGAN: January 22. The Southfield High School Amateur Radio Club's 23rd annual Swap & Shop, Southfield HS, 24675 Lahser, Southfield. 8 AM to 3 PM. Admission $3.00. Reserved tables $20 for two 8' tables payable in advance. All profits go to Electronic scholarships and to support the activities of Southfield HS ARC. For information or reservations write Robert Younker, Southfield High School, 24675 Lahser, Southfield, MI 48034. (313) 746-8637.

FLORIDA: January 29. The Sky High ARC's 9th annual Citrus County Hamfest, New Location—National Guard Armory, Seven Rivers Drive, Crystal River. Doors open for exhibitors 7 AM. General public 9 AM. Admission $3 advance, $4 door. Talk in on 146.355/955, SHARC Hamfest, 5334 S. Forest Terr, Homosassa, FL 32646 for tickets, tables or further information.

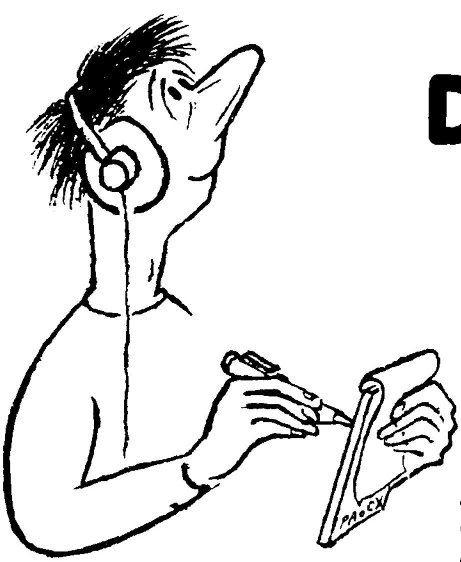
LONG ISLAND, NY. February 5. LIMARC Hamfest, Electricians Hall, 41 Pinelawn Road, Melville. 9 AM to 3 PM. Admission $4.00 all ages. $3.00 after 11:30 AM. 4x6 tables $12. Your own $1.50 per ft. Advance registration only. Talk in on 146.85. Mark Nadel, NK2T, 22 Springtime Lane East, Levittown, NY 11756 (516) 796-2366 or Hank Wener, WB2ALW (210) 694-1811.

OHIO: February 12. The Mansfield Mid-Winter Hamfest/Computer Show, Richland County Fairgrounds, Mansfield. Doors open 7 AM. Tickets $3/advance; $4/door. Tables $6/advance; $8/door. For additonal information, tickets or tables SASE to Dean Wrasse, KB8MG, 1094 Beal Road, Mansfield, Ohio 44905 (419) 589-2415 after 4 PM EST.

MASSACHUSETTS: February 18. Electronics Flea Market sponsored by the Algonquin ARC. Marlboro Middle School Cafeteria, Union Street off Rt 85, Marlboro. 10 AM to 2 PM. Sellers 8 AM. Admission $2.00. Tables $8/advance; $10/door. Wheelchair accessible. Talk in on 146.01/61 and 146.52. For more information Dan, KB1WW (617) 481-1587 or write AARC, Box 258, Marlboro, MA 01752.

MICHIGAN: March 19. The South Eastern Michigan Amateur Radio Association's 31st annual Hamfest/Swap & Shop, Grosse Pointe North High School, 707 Vernier Rd, Grosse Pointe Woods. 8 AM to 2 PM. Advance $2.00; at the door $3.00. Tables $8.00 and $10.00. ARRL and DX forums. Packet Radio demo. Talk in on W8FWC Repeater 146.74/14. For information write SEMARA Swap, PO Box 646, St. Clair Shores, MI 48080. Please SASE or phone N8HLY (313) 526-9498 after 6 PM.

THE MIT UHF REPEATER ASSOCIATION and the MIT Radio Society offer monthly HAM EXAMS. All classes Novice to Extra. Wednesday, January 18, 7 PM, MIT Room 1-150, 77 Mass Avenue, Cambridge, MA. Reservations requested 2 days in advance. Contact Ron Hoffmann at (617) 484-2098. Exam fee $4.50. Bring a copy of your current license (if any), two forms of picture ID, and a completed form 610 available from the FCC in Quincy, MA (617) 770-4023.



DX FORECASTER

Gorth Stonehocker, KØRYW

Better DXing in 1989

Now that the new year's begun, take time to consider ham radio DXing. It should be a new kind of year for this activity. The sunspot number will climb to very near maximum by the end of 1989, so now's the time to evaluate how your station performs on the higher frequency bands. The maximum usable frequency (MUF) for December 1989 is expected to reach 27.5 MHz at midlatitudes. MUF's nearly twice those in recent sunspot minimum years are expected. And, since the last sunspot maximum, we are allowed to use two new bands that we didn't have at the last sunspot maximum. These are 12 meters (usable now) and 17 meters (available July 1, 1989).

If you need a new rig to cover these bands, you may want a more powerful one. But the new bands (particularly 12 and 17 meters) are up where signal absorption isn't usually a great problem. However, you may want to evaluate your antenna's ability to put the signal where you want to DX. The signal increase you'll gain from coupling the antenna to the ionosphere to work your favorite DX area is well worth the effort. Choose the antenna that best increases your station's signal strength by homebrewing or selecting one of the many on the market. Directional antennas are highly recommended and not too difficult to build on 12 meters. A horizontal antenna can be placed high enough (60 feet) to give a signal takeoff angle of 10 degrees for general Dxing, but you'll need to determine the height that gives you the best angle to put the signal at the correct distance. While they are inherently low-angle radiators, vertical antennas need good ground radial systems and correct array phasing to put the best signal at the needed distance and place.

Last-minute forecast

Expect the first and second weeks to have openings in the higher frequency bands (10 to 30 meters). This is due to higher solar flux. Some openings may provide excellent signals to southern countries in the late afternoon and evening. Ionospheric disturbances could enhance these openings near the 5th, 11th, and 18th. Paths to Japan and Europe may have fluctuating signals and lower MUF's during these disturbed periods. Conditions will be favorable for winter absorption anomaly openings 3 to 4 days after the disturbance around the 18th. Check WWV for the STRATWARM announcement, along with the position of the poor signal area and its 180-degree partner. The strong signal openings are at positions in between. These openings are usually for the lower frequency bands near the evening, but do extend into the higher bands.

Lunar perigee is on the 12th; the full moon appears on the 22nd. An intense but short-duration (a few hours) meteor shower — the Quadrantids — will occur between January 2 and 4.

Band-by-band summary

Ten and 12 meters, the highest daylight-only DX bands, are nearest the MUF for Southern Hemisphere paths. They will be open during the 3 to 5-hour period centered on local noon most days when the solar flux is above 150. These bands open on paths toward the east and close toward the west. The paths are up to 4000 km (2400 miles) in single-hop length, and will double on occasion during evening transequatorial openings.

Fifteen and 17 meters daylight-only DX bands (open most of each day) have lower signal strengths and greater multipath variability than 10 and 12 meters. Propagation will be best when the MUF is resting just above these bands, up until the time it drops below them. This transition period occurs soon after sunrise and just before sunset. Transequatorial openings will occur with distances similar to 10 and 12 meters.

Twenty, 30, and 40 meters are both daytime and nighttime DX bands. Twenty is the maximum usable band for DX in the northern directions during the day and, in combination with 30 meters, provides nighttime paths for the day-only bands. Forty meters becomes the main over-the-pole DX daytime band, with some hours covered by 30 meters. This path and east-west paths may be affected by 10-20 dB of anomalous absorption during a few days of the month.

Eighty and 160 meters, the night-only DX bands, exhibit short-skip propagation during daylight hours and then lengthen at dusk. These bands follow the darkness path, opening to the east just before local sunset, swinging more to the north-south near midnight, and ending up in the Pacific areas for a few hours before dawn.

Article L

WESTERN USA

GMT	PST	N (Asia Far East)	NE (Europe)	E (S. Africa)	SE (S. America)	S (Antarctica)	SW (New Zealand)	W (Oceania Australia)	NW (Japan)
0000	4:00	20	30	20	10	12	12	10	15
0100	5:00	20	40	20	12	12	10	10	15
0200	6:00	20	40	20	12	15	10	12	20
0300	7:00	30	*40*	20	15	15	10	15	20
0400	8:00	30	*40*	20	15	15	10	15	20
0500	9:00	30	*40*	*20*	20	15	12	20	20
0600	10:00	30	*40*	*20*	20	20	15*	20	30
0700	11:00	30	*40*	*20*	*20*	*20*	15	20	30
0800	12:00	40	30	*20*	*20*	*30*	15	20	30
0900	1:00	40	*40*	*20*	*20*	*30*	15	20	30
1000	2:00	*40*	*40*	*20*	*20*	*20*	15	*20*	30
1100	3:00	*40*	*40*	*20*	*20*	*20*	20	*20*	*40*
1200	4:00	*40*	*40*	15	20	*20*	*20*	*20*	*40*
1300	5:00	*40*	30	15	15	20	*20*	*20*	*40*
1400	6:00	*40*	20	12	15	20	*20*	*20*	*40*
1500	7:00	30	20	12	12	15	*20*	*20*	*40*
1600	8:00	30	20	10	12	15	*20*	20	*40*
1700	9:00	30	20	10	12	15	20	20	*40*
1800	10:00	40	20	10	10	15	15	20	*40*
1900	11:00	40	30	12	10	15	15	15	30
2000	12:00	40	30	12	10	12	15	15	20
2100	1:00	*40*	30	15	10	12	12	12	20
2200	2:00	*40*	30	15	10	12	12	12	15
2300	3:00	*40*	30	15	10	12	12	10	15

MID USA

GMT	MST	CST	N (Asia Far East)	NE (Europe)	E (S. Africa)	SE (S. America)	S (Antarctica)	SW (New Zealand)	W (Oceania Australia)	NW (Japan)
0000	5:00	6:00	30	30	20	12	12	10	10	15
0100	6:00	7:00	20	40	20	12	12	10	12	20
0200	7:00	8:00	20	40	20	15	15	12*	15	20
0300	8:00	9:00	30	40	20	15	15	12	15	20
0400	9:00	10:00	30	*40*	*20*	15	15	15	20	20
0500	10:00	11:00	30	*40*	*20*	20	20	15	20	20
0600	11:00	12:00	40	*40*	*20*	*20*	20	15	20	30
0700	12:00	1:00	40	*40*	*20*	*20*	20	20	20	30
0800	1:00	2:00	*40*	*40*	*20*	*20*	*20*	20	*20*	30
0900	2:00	3:00	*40*	*40*	*20*	*20*	*20*	*20*	*20*	*40*
1000	3:00	4:00	*40*	*40*	*20*	*20*	*20*	*20*	*20*	*40*
1100	4:00	5:00	*40*	*40*	15	*20*	*20*	*20*	*20*	*40*
1200	5:00	6:00	*40*	30	15	15	*20*	*20*	*20*	*40*
1300	6:00	7:00	20	20	12	15	*20*	*20*	*20*	*40*
1400	7:00	8:00	20	20	12	15	20	*20*	*20*	*40*
1500	8:00	9:00	30	20	12	12	20	20	20	*40*
1600	9:00	10:00	30	20	10	12	15	20	20	30
1700	10:00	11:00	30	20	10	10	15	15	20	20
1800	11:00	12:00	30	20	10	10	15	15	20	20
1900	12:00	1:00	30	20	10	10	15	15	15	20
2000	1:00	2:00	40	30	12	10	12	15	15	20
2100	2:00	3:00	*40*	30	12	10	12	12	12	20
2200	3:00	4:00	*40*	30	15	12	12	12	12	15
2300	4:00	5:00	*40*	30	15	12	12	10	10	15

EASTERN USA

GMT	EST	N (Asia Far East)	NE (Europe)	E (S. Africa)	SE (Caribbean S. America)	S (Antarctica)	SW (New Zealand)	W (Oceania Australia)	NW (Japan)
0000	7:00	*40*	40	20	15	15	15	12	20
0100	8:00	30	40	20	15	15	20	15	30
0200	9:00	30	*40*	20	20	15	20	20	30
0300	10:00	30	*40*	*20*	20	15	20	20	30
0400	11:00	40	*40*	*20*	*20*	20	20	20	30
0500	12:00	40	*40*	*20*	*20*	20	20	20	30
0600	1:00	*40*	*40*	*20*	*20*	*20*	*20*	*20*	30
0700	2:00	*40*	*40*	*20*	*20*	*20*	*20*	*20*	*40*
0800	3:00	*40*	*40*	*20*	*20*	*20*	*20*	*20*	*40*
0900	4:00	*40*	*40*	*20*	*20*	*20*	*20*	*20*	*40*
1000	5:00	*40*	20	20	*20*	*20*	*20*	*20*	*40*
1100	6:00	20	20	15	15	*20*	*20*	*20*	*40*
1200	7:00	20	20	15	15	*20*	20	15	*40*
1300	8:00	20	20	12	12	20	20	15	20
1400	9:00	30	20	12	12	20	20	15	20
1500	10:00	30	20	10	12	15	20	20	20
1600	11:00	30	20	10	10	15	20	20	20
1700	12:00	30	20	10	10	15	15	20	20
1800	1:00	30	20	10	10	15*	15	20	20
1900	2:00	30	20	12	10	12	12	15	20
2000	3:00	40	30	12	10	12	10	12	15
2100	4:00	*40*	30	15	10	12	10	12	15
2200	5:00	*40*	30	15	12	12*	10	10	15
2300	6:00	*40*	30	20	12	12	12*	10	20

JANUARY

The italicized numbers signify the bands to try during the transition and early morning hours, while the standard type provides MUF during "normal" hours.

*Look at next higher band for possible openings.

(continued from page 64)

the polarity of both batteries and the milliammeters. The results were much the same (although the actual numbers were different because the transistor had different characteristics). There was a small amount of leakage current (collector current flow when there was no measurable base current), but the collector current increased smoothly in response to changes in R1.

JFETs operate on a different principle; I'll get into that next month. Until then, why don't you grab a couple of old transistors and see what you can find out?

Article H **HAM RADIO**

product

REVIEW

New high performance Yagi

Cushcraft's 12-4CD is the latest in the line of high performance HF mono-band Yagis. The 12-4CD, scaled from the popular 10-4CD, is designed to cover the new 12-meter ham band. The latest entry into the Skywalker family includes: computer-aided design-optimizing forward gain and maximizing sidelobe attenuation; the 50-ohm Reddi-match feed system (which allows direct connection to 50-ohm coax through a UHF PL-259 connector); rugged construction of heavy-wall, heat-treated 6063-T832 aluminum tubing; and stainless steel hardware. The 12-4CD is designed to cover the entire 100-kHz band segment with a SWR of less than 1.2 to 1, and is rated at 2000 watts PEP.

Antenna assembly was straightforward and simple with Cushcraft's updated instruction sheet. A concise, step-by-step, illustrated instruction manual showed the easiest way to final set-up. To put the antenna together you need a standard straight-blade screwdriver, a small adjustable wrench, and a measuring tape. I put all the parts together in a little more than an hour. After I had assembled the 12-4CD, it took me about 15 minutes to install it on a crank-up tower. The antenna is a delight to work with on towers. It weighs just 21 pounds and has a surface area of 3.9 square feet. It can be easily installed by one person.

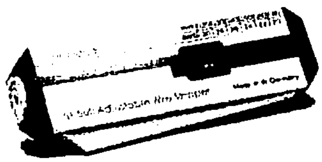
Performance of the 12-4CD is what you'd expect from a high-performance 4-element monoband Yagi. Tuning from band edge to band edge indicated a maximum SWR of 1.3 to 1, with resonance at the center of the band. Although the higher bands (i.e. 12 and 10 meters) have been marginal at best through the summer months here in the Northeast, I was able to make several stateside contacts — all with excellent reports. Owing to the newness of the 12-meter band, and the relative lack of commercial antennas it, I didn't run comparative A-B tests. But from contest experience with Skywalker 10-4CD and 15-4CD beams, I believe this antenna will be a hot performer on 12 meters in the coming years. If you're looking to enjoy DX on 24 MHz and take advantage of our increased spectrum, this antenna will make your signal loud on 12 meters!

NB1H

NEW products

New precision tool stripping wire

OK Industries Inc. has introduced a new adjustable precision wire stripper, the ST-500. The ST-500 strips 20 to 30 AWG wire with four specially hardened blades that handle all types of wire insulations — including Teflon. Simply turn the adjustment wheel to the appropriate wire diameter, put the wire through the hole, squeeze the handle, and turn the tool slightly to withdraw the wire.



The ST-500 also includes an adjustable wire stop, which ensures consistent wire strip lengths.

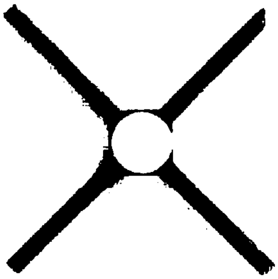
The ST-500 lists for $29.95 and is ex-stock.

For more information about the ST-500 or OK Industries full range of Bench Tools contact: OK Industries Inc., 4 Executive Plaza, Yonkers, New York 10701.

Circle #301 on Reader Service Card.

Low cost, high gain hetero-junction FET

California Eastern Laboratories announces the NE32084 low noise, hetero-junction FET. Low noise and high associated gain make the device



suitable for LNA, gain stage, and OSC applications in DBS, TVRO, and other low cost, high volume products.

The performance features are as follows:

NF: 1.5 dB MAX (1.3 dB TYP) at 12 GHz
GA: 9.0 dB MIN (10.0 dB TYP) at 12 GHz

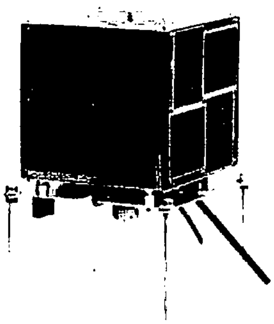
Samples and mass production quantities are available now from California Eastern Laboratories, the exclusive sales agent in North America for NEC RF and microwave semiconductors. For further information contact California Eastern Laboratories, Inc., 3260 Jay Street, Santa Clara, California 95054.

Circle #302 on Reader Service Card.

Consortium pioneers new satellite class

A consortium of Amateur Radio groups (AMSAT-NA, AMSAT-LU, and BRAMSAT — Brazil AMSAT) and Weber State College, Ogden, Utah are working together to construct and launch a new class of ultra-compact "micro-satellites" so small they can be launched on virtually any launcher. The Tucson Amateur Packet Radio (TAPR) organization is providing initial financial support and ARRL is assisting with design and construction support.

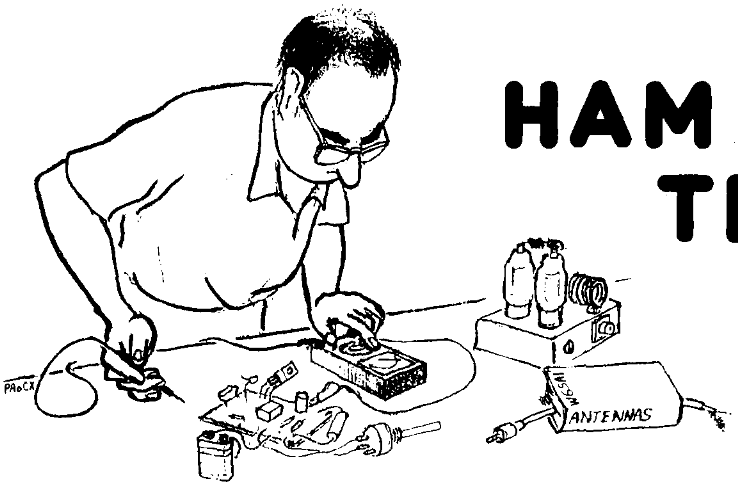
Each satellite consists of a common design bus. Each bus carries a mission-specific payload. AMSAT-NA and AMSAT-LU payloads are packet radio transponders. BRAMSAT's payload is a voice synthesizer transmitting easily-heard



VHF FM downlinks. The Weber State College payload is an earth-looking CCD camera.

The most unique characteritic of each satel-

(continued on page 106)



HAM RADIO TECHNIQUES

Bill Orr, W6SAI

A balun for 10 meters

More so than the lower frequency bands, 10 meters is a hostage to the sunspot cycle. When the sunspot count is low, the band is dead. Only spotty, occasional DX shows up as a result of sporadic E or other chancy forms of propagation.

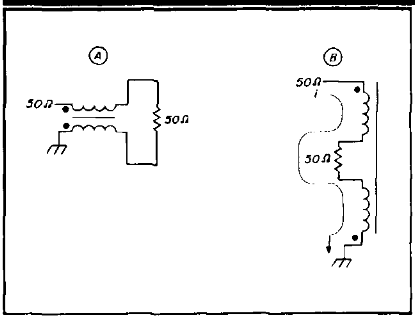
However, when the sunspot cycle is comfortably high the 10-meter band is a DX operator's paradise. Signals boom in from all parts of the world, often with astounding strength. Many recently licensed Amateurs have never had the thrill of 10-meter DX. But after a false start last spring 10 meters is jumping once again, and there's great interest in 10-meter antennas and antenna accessories.

Judging from my mail and conversations with newly licensed hams, the antenna balun is a confusing topic. I hear these questions: What is a balun? What does it do? Do I need one?

How the balun works

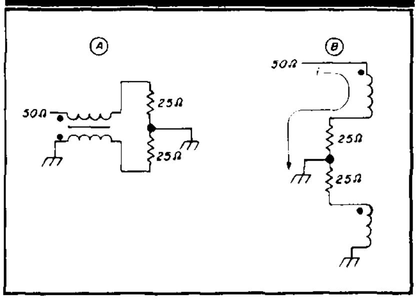
Let's look at the workings of the balun first. The word "balun" stands for "balance-to-unbalance". This implies that a balun provides two equal and opposite-phase voltages with respect to ground when driven from an unbalanced source, like a coax line with one conductor at ground potential. The balun is an ideal device for connecting a balanced antenna (such as a dipole) to a coax line.

FIGURE 1



(A) One-to-one, two-conductor balun matches ungrounded load. (B) Equivalent circuit shows magnetizing current (i) flowing through windings and load.

FIGURE 2



(A) Two-winding balun connected to grounded, balanced load. (B) Equivalent circuit shows magnetizing current (i) no longer flows equally in the windings and the load.

From another point of view, the balun provides isolation between the coax outer shield and the half of the dipole connected to it. If the balun were not present, some of the current flow in the coax shield would be present on the outside of the shield — not the inside. The current on the outside of the shield can radiate into space, making the coax line part of the antenna.

In the case of a beam, outer shield current can ruin an otherwise good front-to-back ratio, cause loading difficulties, and even lead to TVI and RFI problems. It can also cause erroneous SWR readings regardless of antenna type.

Some beam antennas and dipoles come with baluns, others don't. You can buy or build a balun if you want one. Building a balun isn't difficult, especially for 10 meters.

The 1:1 balun

There are many forms of baluns; the most popular Amateur type is the 1:1 design. This implies that when the balun is used with a 50-ohm coax line, it provides a balanced 50-ohm termination. Amateurs have found that this simple balun works well with balanced antennas having a feedpoint

impedance as low as 20 ohms, or as high as 80.

The simplest form of 1:1 balun is a choke coil made of coax line. The line is wound into a multi-turn coil about ten times the diameter of the coax. Most designs specify six to eight turns (**fig. 1A**). The electrical equivalent of this balun is shown in **fig. 1B.** The balun may be either air wound, or wound on a ferrite or powdered-iron core. (More about the core material later.)

If the balun is connected to a balanced and "floating" load (one that is not grounded), the balun will do the job. The magnetizing current (the current that creates the magnetic field in the core) is balanced in the windings and doesn't upset the balanced output voltages. You can see this in **fig. 1B**.

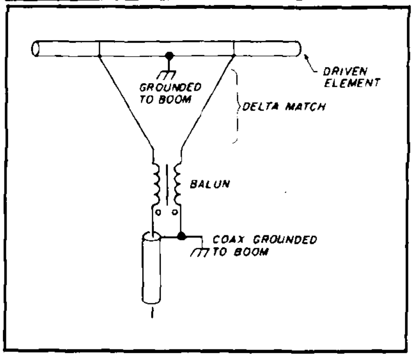
There's no guarantee that the driven element of the antenna is really balanced in an electrical sense. The degree of balance depends upon physical and electrical characteristics (mounting technique, parasitic capacitances, proximity of coax line, etc.) that you can't measure or control. One solution to this problem is to physically ground the center point of the antenna (**fig. 2A**). The load is no longer floating to ground, but the magnetizing current no longer flows equally in the windings and the load! It's shorted to ground by the ground point of the antenna (**fig. 2B**).

Here's an example. Some beam designs employ a balun and delta-match feed system with the driven element grounded to the boom of the array (**fig. 3**). Intuition tells you the design is practical, but the illustration in **fig. 2B** clearly shows that half of the feed system isn't working; the magnetizing current isn't flowing through one balun winding. The two-winding balun isn't doing the job it's supposed to do.

The three-winding balun

In many cases the two-winding balun (coax line wound up into a coil) feeding an ungrounded, floating dipole is adequate. A better solution is the three-winding balun shown in **fig. 4A**.

FIGURE 3



Two-winding balun (coax balun, for example) is shorted out when coax shield and center of driven element are grounded to boom of antenna.

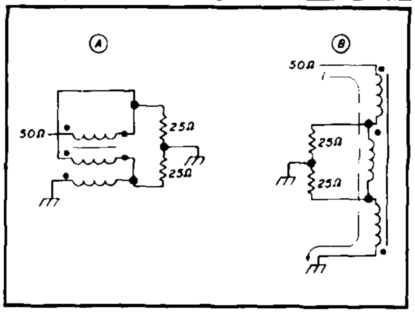
The third winding provides a path for the magnetizing current around the load, regardless of whether the load is floating or not (**fig. 4B**). Note that the polarity of the third winding is reversed. This is the ideal solution to the problem. The majority of 1:1 baluns on the market are made in this configuration. The simple coil-type coax balun can be readily converted into a three-winding balun. I'll tell you how in the next section.

A homemade balun for 10 meters

Figure 5 shows a simple and inexpensive air-core three-winding coax balun you can build. The balun is usable over the range of 14 to 30 MHz. You'll need a 25-1/2 inch length of RG-8A/U, a PL-259 plug and 3 feet of plastic covered no. 12 single conductor wire, available from most hardware or home improvement stores.

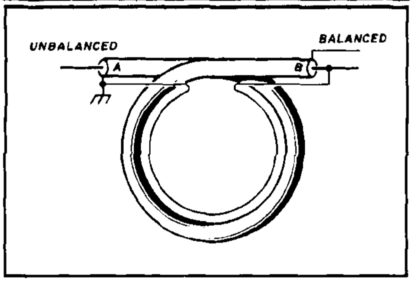
First place the PL-259 on one end of the coax cable. Next, remove 2 inches of the outer jacket of the opposite end of the line. Unbraid the outer braid and twist it into a pigtail. Now remove about an inch of the inner insulation. Place large soldering lugs on the two conductors. You'll attach these to the terminals of the driven element. The exposed joint needs to be carefully covered later with CoaxSeal™ Radio Shack Connector Sealant 278-1645, or equivalent to make sure water doesn't enter the coax cable.

FIGURE 4



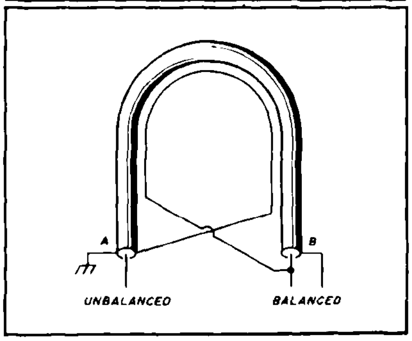
Three-winding balun (A) can feed either grounded or ungrounded load and maintain magnetizing current (B).

FIGURE 5



Coax balun performs properly when third winding is added. Extra winding is cross connected to coax at the ends. (Actual balun has two turns.)

FIGURE 6



Simplified balun drawing showing cross connections.

Winding the balun

Next, wind the coax into a two-turn coil; leave about two inches of coax free on each end. Do this by manipulating the size of the coil. The coax plug and pigtails should lie very close to each other on the same side of the coil. Hold the coil in position with bits of vinyl tape.

Now add the third winding to the coil. Carefully wind the plastic-covered wire in parallel with the coax. This is easy because there are only two turns to the coil. Smooth the wire up against the coax and tape it in place every few inches. When you've finished, the wire will be running closely parallel to the coax and you can tape the coil completely.

Finally, attach the wire to the coax winding. If the coil size is right, there will be about 2 inches (or less) of coax free of the coil at each end. The wire winding is cross-connected at the ends of the coax. (See **fig. 6**.) The end of the wire nearest end A of the coax is connected to end B of the coax. Do this by soldering one end of the wire to the shell (not the ring!) of the PL-259 and the other end of the wire to the free center conductor lead, just before it enters the soldering lug. Trim the ends of the wire as you proceed so that no loose wire is left at either end of the coil. After everything's in place, wrap the complete coil again with vinyl tape and waterproof the wires at one end of the balun with the coax tape.

That's all there is to it! The power rating of the balun is the same as that of the coax line.

You can also make a smaller, lighter balun for low-power applications by substituting RG-58B/U coax for the RG-8A/U. A PL-259 plug and UG-175 reducing adapter are used at one end of the balun; otherwise, all is as described earlier.

Modifying the balun for wideband use

The three-winding coax balun can be modified for lower frequency use. If you use three turns instead of two for both windings, the operating range of the balun is 7 to 30 MHz; with five turns, the range is 3.5 to 18 MHz. A six-turn design didn't work very well as it was difficult to hold the wire coil in close proximity to the coax coil.

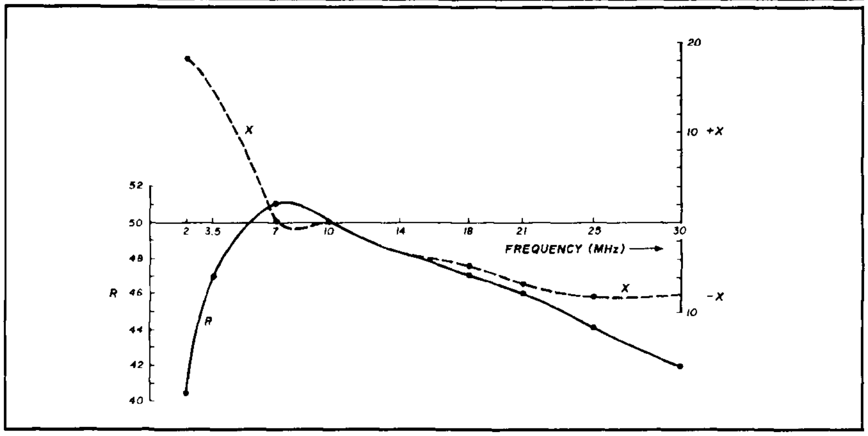
The ferrite-core balun

The air-core balun I've described is somewhat limited in low-frequency response. Even the five-turn design wasn't too good at the low-frequency end of the 80-meter band. You can extend the low-frequency limit by adding turns to the balun, but it's difficult to make an air-core balun that's electrically unbalanced function properly on the 80-meter band.

The solution is to use a higher permeability core. Both ferrite and powdered-iron cores that will do the job are available. The core can be a rod or a toroid. At the higher frequency end of the spectrum the core is almost "invisible," but the core is most important as the frequency of operation is lowered. At 80 meters, the entire balun field is contained within the core. Some manufactured baluns must be derated on 80 meters to prevent the core from running too hot. Many of them won't function at all on 160 meters. But the need for a balun on the lower bands is questionable; few highly directional antennas are used at these frequencies. In the case of a simple antenna like a dipole, current flow on the outside of the coax is no big deal. If the coax line is made an odd multiple of a quarter wavelength (1/4, 3/4, etc.), and an effective ground is used on the transmitter, current flow on the outside of the coax will be at a minimum.

The perfect balun really exists only in the laboratory; practical low-cost baluns work, but exert some influence on antenna resonance. Wideband, Amateur-style ferrite-core HF baluns usually have a design frequency of about 10 MHz and are useful over the 3.5-30 MHz range. Air-core coax-wound baluns have about the same design frequency, but are useful only down to about 4 MHz. In either case, above or below the design frequency, the balun appears as a reactive load and introduces its own SWR anomaly into the picture. **Figure 7** shows the SWR response of a typical wideband balun working into a 50-ohm load. The balun is good, but not perfect. The reactive effect of the balun, when you're operating with an antenna, is to move the resonant frequency of the antenna either higher or lower. A beam cut to 14,150 kHz, for example, may seem to be resonant at 14,220 kHz and "look like" 48.5 ohms when checked through a 50-ohm balun.

FIGURE 7



Ferrite-core trifilar balun shows good response between 6 and 25 MHz. Performance is poor at 80 meters (3.5-4.0 MHz) and 10 meters (28-30 MHz). Balun is terminated in 50-ohm noninductive load.

Dial cards for the TL-922A amplifier

I was working Bob, KL7DJI, in Fairbanks, Alaska the other day; he gave me a great idea for tuning charts for a linear amplifier. I made up a set, and they have proved invaluable for quick band changes (**fig. 8**).

The idea is simplicity itself. Cut a dial card from heavy paper. (I used index cards to make mine.) Slot the card to

(continued on page 109)

NEW products

lite is its volume and mass. Only 23 cm (9 inches) on a side, each cubical spacecraft will weigh in at less then 10 kg (22 lbs.). The small mass and volume make it feasible to launch these spacecraft inexpensively.

AMSAT officials say this new class of satellites uses advances in microminiaturization, advanced RF devices, and modular construction to pioneer a new niche in performance/mass/volume for satellites.

AMSAT-NA has contracted for an early 1989 launch for the first four satellites. The four satellites will be launched into a polar, low earth orbit by Arianespace early next year. The primary payload will be the French SPOT-II mission.

For more informantion, contact AMSAT Information Officer, Vern Riportella, P.O. Box 177, Warwick, New York.

Circle #303 on Reader Service Card.

Free catalog of tools and test equipment

Jensen Tools Inc. offers a free catalog of tools and test equipment. Illustrated in full color, the 160-page catalog lists many new products.

The catalog features over 50 tool kits. Other major categories include: hand and power tools (English and metric), tools and accessories for fiber optics and wire/cable systems, static control products, soldering/desoldering supplies, lighting and optical aids, circuit board accessories, test cables, carrying cases and shipping containers.

For your free catalog, write or call Jensen Tools Inc., 7815 S. 46th Street, Phoenix Arizona 85044. (602)968-6231.

Circle #304 on Reader Service Card.

New computer interface option

Advanced Computer Controls, Inc. announces the new computer interface option for the RC-850 Repeater Controller. The interface opens up remote control, programming and information access to FM repeater systems from a home computer or terminal via telephone modem or packet TNC.

The user interface resembles a packet BBS. It's menu driven with lots of on-line help.

Information that can be downloaded from the controller includes a "front panel display," command log, metering information, activity information, and the contents of the programmable memory. All controller commands may be entered through the remote terminal with text responses displayed on the terminal screen. Programmable speech and Morse code messages stored in the controller may be viewed directly as text. They can be reprogrammed by typing the letters and words directly, without referring to vocabulary codes.

Two additional Touch-Tone decoders on the Computer Interface board offload the main shared decoder for full-time coverage of links and remotes, and the telephone line.

A Vocabulary Expansion Option increases the

size of the synthesized speech vocabulary to 530 words.

The price of the Computer Interface Board is $350; the Vocabulary Expansion Option is $75. For additional information, contact Advanced Computer Controls, Inc., 2356 Walsh Avenue, Santa Clara, California 95051. Or call 1-408-727-3330.

Circle #305 on Reader Service card.

MFJ-986 3 KW differential-T antenna tuner

MFJ Enterprises, Inc. has introduced the new MFJ-986 3 KW Roller Inductor Differential-T Antenna Tuner. This unique design uses a single differential capacitor in place of two variable capacitors. It covers 1.8 to 30 MHz continuously, including MARS and all the WARC bands.

The differential capacitor makes tuning easier because you get minimum SWR at only one setting and have only two controls to adjust. It also gives you a broadband response that eliminates constant retuning.

A three-digit turns counter plus spinner knob gives precise inductance control for instant return to a favorite frequency.

The compact 10-3/4″ × 4-1/2″ × 15″ aluminum cabinet has plenty of room to mount the silver-plated roller inductor away from metal surfaces for highest "Q" and maximum power into your antenna.

A lighted two-color peak and average reading Cross-Needle SWR/Wattmeter lets you read forward and reflected power and SWR at a glance. It also has a new directional coupler that gives more accurate SWR and power readings over a wider frequency range.

A six-position antenna switch lets you select two coax lines and/or random wires (direct or through tuner), balanced line and external dummy load.

A new current balun for balanced lines reduces feedline radiation, field pattern distortion, and TVI. Ceramic feedthrough insulators for balanced lines withstand high voltages and temperatures.

The new MFJ-986 3 KW Roller Inductor Differential-T Antenna Tuner is priced at $239.95 and comes with MFJ's one-year unconditional guarantee.

For more information or your nearest MFJ dealer contact MFJ Enterprises, Inc., P.O. Box 494, Mississippi State, MS 39762, or order toll free at 800-647-1800.

Circle #306 on Reader Service Card.

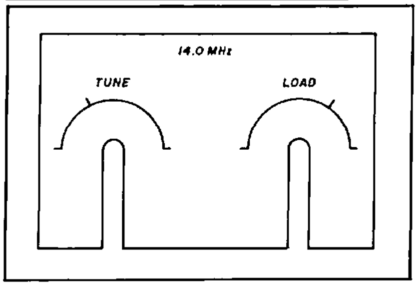
QD-2 Quick Disconnect

Hustler, Inc. announces a new and improved Quick Disconnect, Model QD-2. The QD-2 is similiar to the original model QD-1 but features a new design for the lower half. The QD-2 is milled from a solid piece of stainless steel and comes with a 2-year warranty. For further information contact the Sales Department, Hustler, Inc., 1 Newtronics Place, Mineral Wells, Texas 76067.

Circle #307 on Reader Service Card.

(continued from page 105)

FIGURE 8



Dial card for TL-922A amplifier. Cursor marks enable fast tuning. One card is made for each band.

drop down behind the "tuning" and "loading" panel controls. You'll need one card for each band.

Tune and load the amplifier and transfer the dial settings to the card. Just mark a line on the card that corresponds with the line indicated on the dial. Then, when you retune, slip the proper band-dial card in place and readjust the dials to the marks. This idea also works well with the various transceivers that have adjustable tuning and loading controls.

The "Dead Band" contest

Aha, you Couch Potatoes! I really caught you with my second quotation quiz! The cable:

STORY TRUE. AWAIT ME
ALGIERS. BURROUGHS

is the beginning of *Pellucidar*, by Edgar Rice Burroughs. This is the transatlantic cable sent by Burroughs to Cogdon Nestor, who had found the telegraph line laid by David Innes connecting the Sahara Desert to Pellucidar — 500 miles below the earth's surface.

To date (late August), the only sharp-eyed readers who identified the famous cable are: Bob Clarke, N1RC; John Brown, G0GJB; and Bill Lathan, AK5K. Good work! My condolences to W0TDH, NW2V, W9VE, and W5OWS who came close.

Thanks to the following detectives who correctly identified the quote from Sherlock Holmes: Gerry Skloot, KE2N; Howard Tooker, W3TL; Ben Richardson, WB1CUA; Louis Axeman, Jr., N8LA; Dan Deckert, WA6FQC; Mike Mahoney, WA1KNO; Chris Kirk, KA1RSV; Dave Fordham, KD9LA; Peter Chadwick, G3RZP; Charles Rhine, AA0M; Cliff Watkins, KB7ADF; Jeff Rahmel, KA8ZAW; John Peak, KE6HS; Don Murray, W9VE; Jim Josenhans, WB2LEH; Bob Clarke, N1RC; John Nagle, K4KJ; and Dale Hunt, WB6BYU. Congratulations to all!

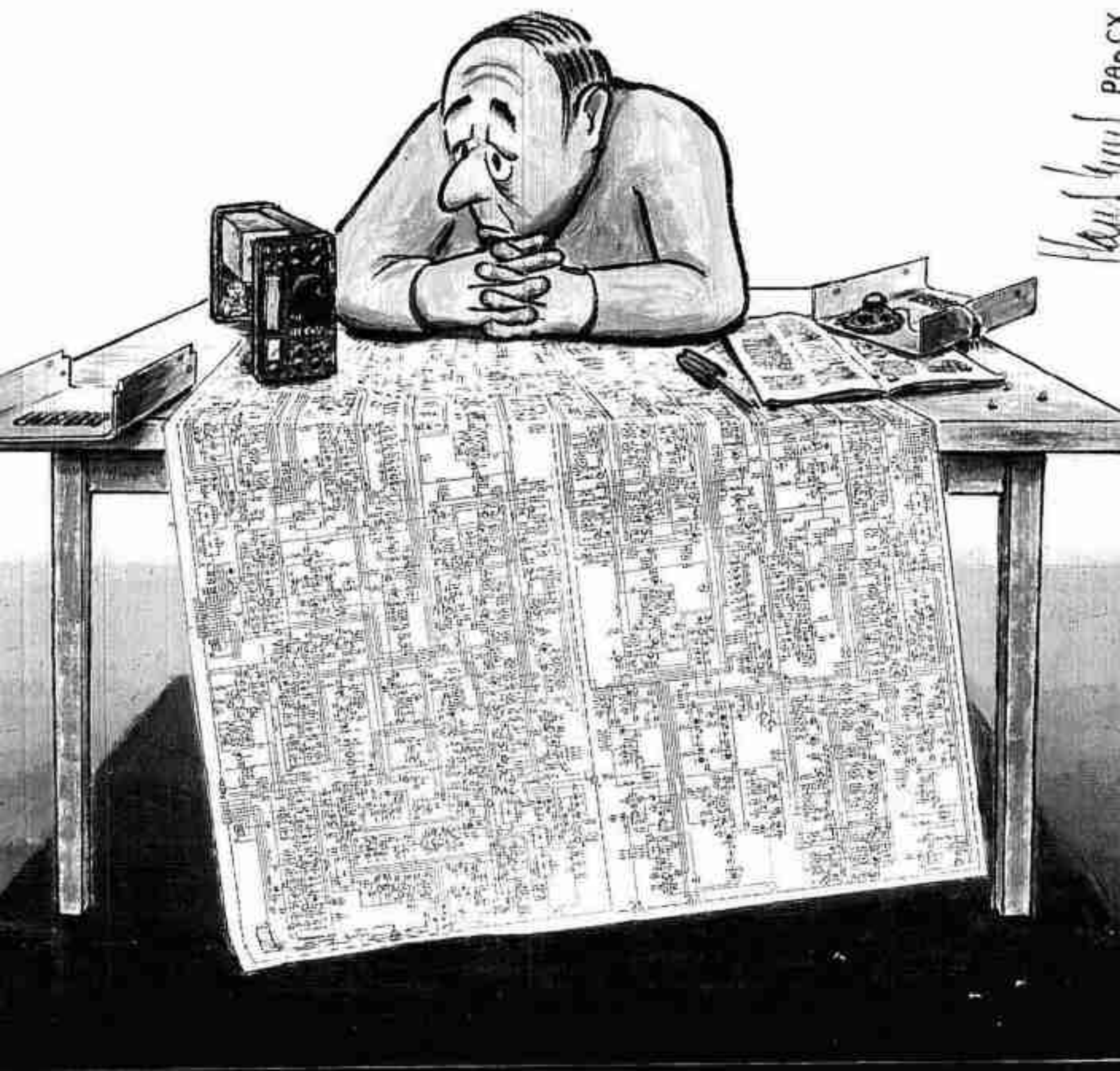
This month's "Dead Band Quiz" is an easy one. Name the book and author. If you don't know, ask your XYL or girl friend: "Last night I dreamt I went to Manderley again."

If you think you can identify this quotation, drop me your answer on a QSL card: Box 7508, Menlo Park, California 94025. Good luck!

Article M **HAM RADIO**

FEBRUARY 1989 / $2.50

HAM RADIO



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FEBRUARY 1989

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FEATURES

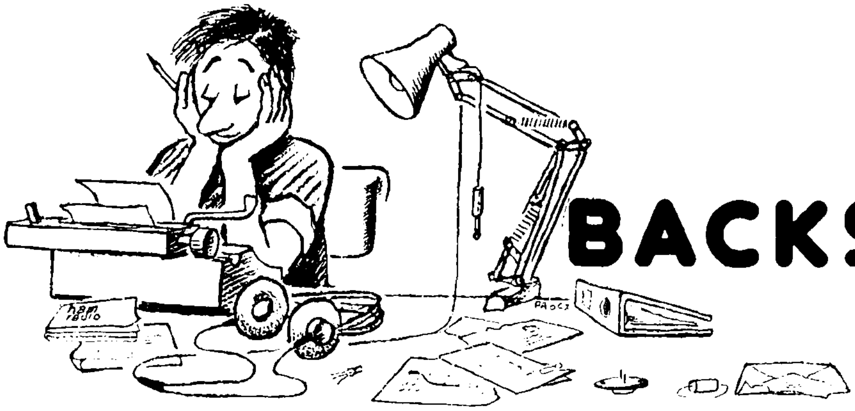
W1JR, page 42

K4IPV, page 82

THE WEEKENDER
N2DCH, page 24
K1ZJH, page 94

See page 17 for the winners of December's handheld radio contest.

DEPARTMENTS



BACKSCATTER

Glasnost and Amateur Radio

It's fascinating how the "Iron Curtain" has opened in the past few months. First a group of Russian and Finnish hams operated from Malyj Vysotskij Island; then jamming of several shortwave broadcasters stopped. Now, there's the amazing story of how the International Amateur Radio Network (IARN) was able to get two operators and $10,000 worth of radio gear into the Soviet Union to help with the Armenian relief effort! This would have been unheard of 10 years ago. Today, it could signal the beginning of a new era of cooperation between the USSR and the rest of the world.

Recently, the ARRL participated in assembling portable battery-operated packet stations. The first complete stations were shipped to Moscow on December 19th. The RSGB's Raynet Organization activated its International Emergency Center, and has been cooperating with the British Red Cross and the UK Overseas Development Agency. We thought you'd enjoy the following piece as a sample of some of the ham activities you'll read more about shortly.

(Thanks Westlink and W9ELR)
de N1ACH

A Christmas Present To Armenia

On December 14, 1988 the IARN, an all-volunteer Amateur Radio organization, asked for people to go to Moscow and help the Soviet Amateur Radio Operators set up much-needed radio circuits between earthquake-ravaged Armenia and the rest of the world. Nearly $10,000 of sophisticated radio communication equipment had been donated by various manufacturers and charitable organizations for this purpose.

Charles Sheffer, KJ4TY, of Apalachicola, Florida and I flew to Cleveland, Ohio to meet with a handful of dedicated Amateur Radio operators (headed by Dave Speltz, KB1PJ) to coordinate and finalize plans for this humanitarian effort.

Glenn Baxter, K1MAN, of Belgrade Lakes, Maine, head of the IARN, had obtained permission from the Soviet Union for this person-to-person assistance. This was a tremendous breakthrough between two great powers.

KJ4TY and I finally left JFK Airport in New York on December 17th. Aeroflot, the U.S.S.R.'s airline, had agreed to fly us (and all of our radio equipment) to Moscow, at no expense. The Aeroflot personnel were very helpful and put all the radio equipment aboard the plane as our personal baggage.

After an 8-hour flight, we arrived in Moscow and were met at the airport by Soviet officials and representatives of the Soviet Union Amateur Radio community. The officials helped us through customs, waiving all red tape so we could enter the country. We were greeted cordially and, after the proper introductions, were taken to our hotel. During our stay, we had a car, driver, and an interpreter at our disposal.

We eagerly awaited an appointment with the local Amateur Radio organization to finalize plans for assisting them in setting up the emergency communications links between Armenia, Moscow, and the rest of the world.

On our third day in Moscow, we were called into a meeting and told that we must leave the following day. Officials explained that the Aeroflot had reservations booked for nearly a year. They also explained that there were so many foreign assistance personnel in Armenia already, that it was beginning to interfere with the total relief program. They felt that their own Amateur Radio operators could set up the necessary communication links. Having met with some of the local Amateurs, we heartily agreed that they could do the job.

Early the next morning, Soviet officials picked us up at our hotel and drove us to the airport. We left all the radio equipment for use in the emergency networks.

The Soviets seemed extremely grateful for the equipment. They gave us a parting gift and thanked us time and time again for our efforts.

Amateur Radio operators worldwide had been rooting for us, and had assisted with communications in preparation for this trip. This was the first time that anything of this magnitude had been attempted with the Soviet Union. As our efforts were purely humanitarian, we feel that a great stride forward has been made for closer and peaceful cooperation between two great countries.

Our Christmas present to the Soviet Union will prove, in a small way, that people on this planet can work together for a better, more peaceful world.

Al Vayhinger, W9ELR

COMMENTS

Attracting or discouraging newcomers

Dear HR

Your editorial and some letters in the August issue raised some good points why Amateur Radio still has problems attracting newcomers, but I feel the major reasons were not really addressed.

Forget the old excuse about ham equipment costing too much today—gear has always been too expensive for younger amateurs! My first rig was a Heath HW-16, which ran for a little over $100. That might sound like a terrific bargain, but $100 was my parents' monthly mortgage payment.

I think you can make a good case that new hams today have an easier time of equipping their stations than newcomers did two decades ago. There are plenty of used rigs around from the late 1970s, which do an excellent job on CW and SSB and can be had for well under $500. These are tube rigs, to be sure, but it doesn't take long to properly tune one up when changing bands. You can also get on 220 or 10 with a new rig for well under $500. Cost clearly isn't the problem.

Is there really any demand at all for a "bare bones" transceiver at about $500? The folks at Ten-Tec have marketed a very similar rig, the Argosy, for several years with only modest sales; I hear rumors that it's been discontinued. In the August issue, W1FB asked what happened to the concept of high volume and low per-unit profit. What happened is that there's no "high volume" to speak of today in the ham radio market — by its very nature, it's a low volume, high markup business. Using W1FB's reasoning, *HAM RADIO* could really increase its circulation by lowering the subscription price to $5 per year! If W1FB thinks there's money to be made by manufacturing a $500 transceiver, he should do it and get rich. (Or go broke...)

The problem is not a lack of technical interest or smarts amoung young people. If you're one of those rare hams with an interest in computing above the Commodore-64 level, you've seen how rapidly teenagers can master C and assembly programming and discuss the intricacies of the MicroChannel data bus. They're learning and having fun, and being a computer whiz is "cool" in a lot of circles. Many of these youngsters would have been attracted to Amateur Radio in the past. (As an aside, the microcomputer industry has quite a few former Amateurs who left the hobby for computing. The most famous of these is Steve Wozniack, the co-founder of Apple Computer.)

So why are we not seeing the expected influx of newcomers from Novice enhancement? Consider the following:

1. Radio is no longer something mysterious or exciting. This is the era of instant worldwide communications by satellite. Even in the mid-1960s, the idea of being able to talk to someone thousands of miles away seemed like science fiction, and there was a natural curiosity as to how such an amazing feat could be accomplished. Youngsters today have grown up with live television from the moon, direct-dialing to foreign countries, and cordless telephones. Radio is an accepted fact of their lives, not an exciting innovation. They have little reason to get excited about owning or operating a radio station. (If they only want to engage in aimless chatter by radio with a group of friends, there's always CB.)

It's interesting to look at some old technical magazines in a good library. At the turn of the century, electricity was the big thing and entire magazines were devoted to experiments with it. As electricity became commonplace, interest in experimenting with it died out — and so did the magazines. We're doubtlessly seeing a similar phenomenon (hopefully to a smaller degree) with radio.

2. Amateur radio has been "curmudgeonized." In the August issue, W1FB wrote that "...a large portion of the fraternity consists of retirees who must exist on fixed incomes." That's obvious to anyone who listens to the General portion of 75 meters. Suppose you're a teenager. Would you want to talk to a bunch of people old enough to be your grandfather? I'm 35 and have a hard time finding someone interesting stateside to have a ragchew with. Can you imagine what it must be like for someone who's 15? Moreover, I have a feeling that a lot of older (in a mental, if not chronological, sense) Amateurs dislike youngsters. There's a letter in the August issue complaining about a generation of "gimmies" who "...are accustomed to essentially getting everything that they want." I don't think I'd have much to say to such a person on the air, and I doubt if many young potential Amateurs would either.

3. A lot of Amateurs don't want growth. This is Amateur Radio's dirty little secret. I recently spoke with a non-ham who had been instrumental in producing the licensing materials now sold through Radio Shack stores. He attended Ham-Com in Dallas and sat in on a session about attracting newcomers. He was shocked at the number of hams there who were quite vocal in their desire for fewer, not more, Amateurs. I told him he should listen to our bands sometime!

4. The ham industry isn't involved as it must be for its own future. One of my hobbies is scuba diving. Go into a dive shop and ask about becoming certified. They won't let you go until you've signed up for a course! Now walk into your local ham dealer and ask

about geting licensed. You might be referred to a local club.

The diving industry recognizes it has to take the initiative to train new divers, thereby increasing its customer base and assuring future profits. Major manufacturers and local ham dealers must adopt a similar attitude instead of leaving it up to an overloaded ARRL and local clubs.

5. We need some form of code-free license. Actually, this would merely restore an old tradition to Amateur Radio, since many (if not most) people who obtained a Conditional or Technician license prior to 1976 never really learned CW. (Don't take my word on it; look at the results of those the FCC called in for re-testing!) What is so terrible about substituting stiffer theory for CW above 144 MHz, or maybe having a modified form of the old Novice ticket authorizing FM on 220 but with a expiration limit of one or two years? A no-code license is not a panacea for slow growth, but it would help.

The most interesting thing about the idea of a code-free license is the hypocrisy it brings out in the Amateur ranks. Ever notice how many of the strongest defenders of the code don't have the Extra? If CW is that essential (and easy), may I humbly suggest they take some of the energy they use opposing no-code and get their CW speed up to 20 WPM?

I got interested in Amateur Radio early enough to enjoy Rod Newkirk's DX column in *QST*. He ended one column devoted to increasing QRM on the bands by remarking that we must have more Amateurs. Our choice, in Rod's terrific phrase, was either QRM or QRT. His words are just as applicable today. I want to enjoy Amateur Radio for several more years. But it will not be possible without a sustained flow of younger recruits in the ranks and changes in the structure of the service. We need realistic thinking, not chimeras or warm nostalgia.

Harry Helms, AA6FW,
San Diego, California 92126

Applause for Net Control Operators

Dear HR

As I sit here, for the third day, monitoring the FCC Emergency Frequencies of 14.325 and 14.275, I am appalled at what I hear. There are not only the overly enthusiastic hams who try to assist when no assistance is asked for by Net Control, but those who intentionally and with malice cause interference. Then there are those who think that their questions and messages are the most important ones and should be answered without regard to, and before all others.

For those who fall into the category of causing malicious interference there is no solution other than trying to identify them and suspend their licenses. If they think that they can not be identified they are mistaken. Fellow Amateurs, let's do our thing and self-police the bands.

As to the over enthusiastic hams, please follow the instructions of the net control operator. It is obvious from monitoring the nets that the net control operators not only know what they are doing, but are doing an outstanding job under the circumstances. Let's NOT add to their problems.

As far as those who have health and welfare (H & W) traffic, remember LIFE and DEATH traffic M U S T come first. I also have H & W traffic and have a deep interest in seeing that it gets into the system. However, I wait and follow the instructions of the Net Control.

Having been an Amateur for over 25 years and a net control operator for a good number of years, while serving in the military, I know how demanding the job is. My hat off to all those who served as net control operators during the Hurricane Gilbert emergency. Thank you for your outstanding devotion to Amateur Radio.

David L. Schwein, N4OBU,
Sebring, Florida 33870

A $40 DIGITAL VOICE STORAGE ID'ER

By Carl Lyster, WA4ADG, 4412 Damas Road, Knoxville, Tennessee 37921

Use this device to reproduce up to 6.4 seconds of voice

I have designed and built a digital voice storage device capable of reproducing up to 6.4 seconds of human voice. The basic design can be expanded to provide longer and/or multiple messages.

Theory of operation

To understand digital voice storage, first assume that you want to record a 1000-Hz, zero to 5-volt sine wave. If you were to "freeze" the sine wave for an instant, you would observe a DC voltage somewhere between zero and 5 volts. You'd record the readings in a notebook and plot them on a piece of graph paper. Then you would "release" the sine wave and freeze it again 1/10,000th of a second later. The recording and plotting of this new value would show it to be slightly different in amplitude. If you were to repeat this process 10,000 times, you would have a written record composed of 10,000 voltage data points representing 1000 cycles of the sine wave, and a graph to prove it! Now try the experiment using real world electronics to accomplish the same results.

In place of a voltmeter, use an analog-to-digital converter (ADC) chip — an IC that measures a DC voltage and converts it to a binary number. Store the data points on some RAM memory chips (instead of in a notebook) and use a quartz crystal timebase to accurately time the 1/10,000th of a second sampling intervals. Before running the experiment, make one last change. This time try sampling the output of an amplified microphone instead of recording a sine wave.

Speak into the microphone until you use all of the RAM storage space. You now have a digitized human voice stored in the RAM memory. Program a ROM memory chip with the exact data contained in the RAM memory chips to make a permanent copy of the recorded voice. An *almost* indestructible voice recording is stored in the ROM memory chip!

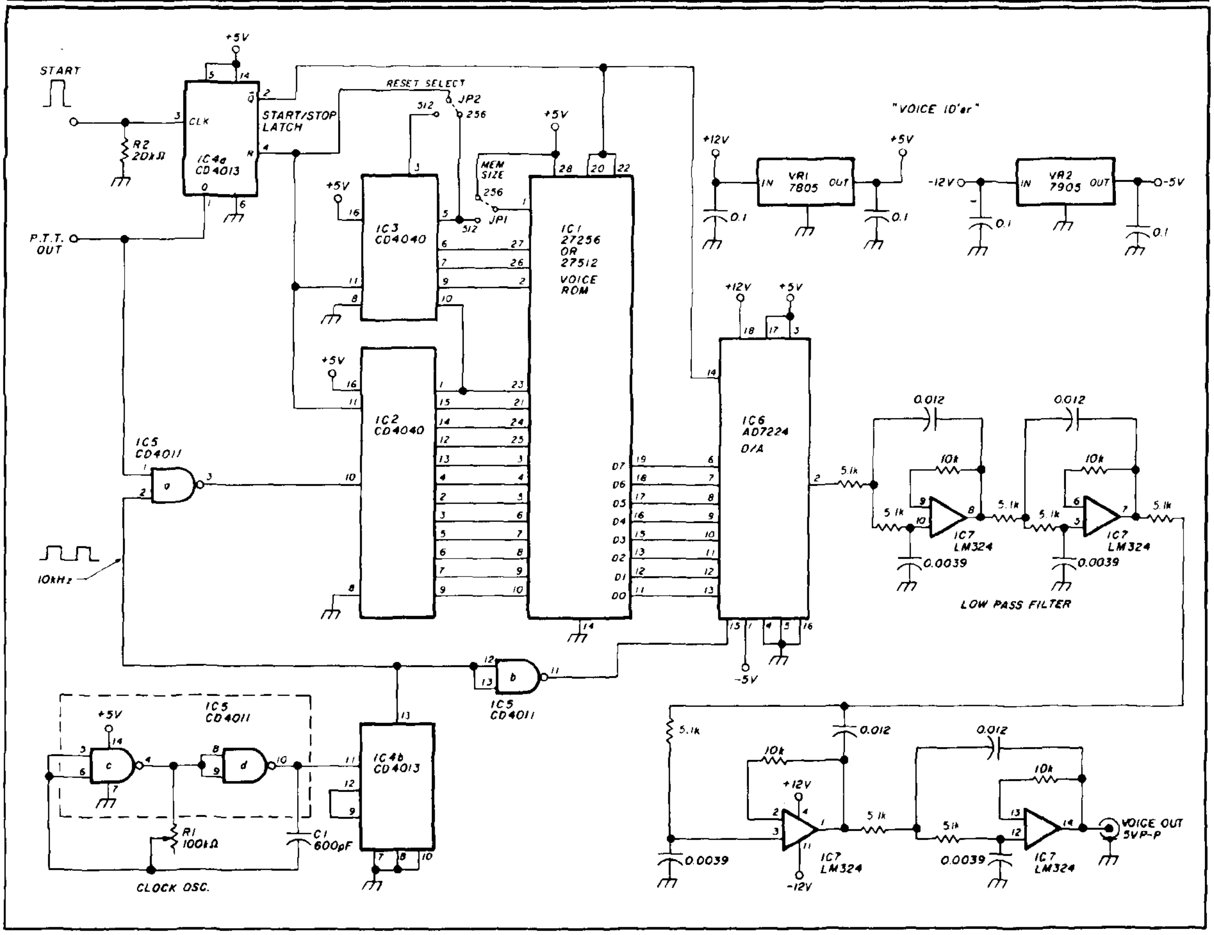
How do you recreate the voice stored in ROM? Retrieve the data from the ROM chip one data point at a time, with a spacing of exactly 1/10,000th of a second between data points. Feed each data point one after the other to an IC called a digital-to-analog converter (DAC). This chip takes a binary number representing a voltage and generates that voltage as its output. The data points entering the DAC cause a varying voltage output which is an exact duplication of the amplified microphone's output.

Now let's get to the ones and zeros of how this $40 wonder works.

Technical description

Assume that the ROM chip has already been programmed with the desired voice passage (more on this later). Refer to **fig. 1**. IC4 is a CD 4013 dual flip flop. One flip flop is used as the start/stop latch. A positive going 5-volt input pulse toggles the Q output high and the Q bar output low. The Q output of the start/stop latch is used as an active high PTT signal to key external repeater logic. The Q output also gates the 10-kHz sampling clock at IC5a, and the Q bar signal enables the chip select lines of both the ROM and DAC. Two gates of IC5 (c and d) form an adjustable oscillator running at 20 kHz. Pot R1 sets the frequency of the oscillator and can be used as a "pitch adjustment" to fine tune the voice tone. The 20-kHz clock is divided by 2 in IC4b, which gives the required 10-kHz sampling clock and ensures a 50-percent duty cycle. The 10-kHz clock is inverted by IC5b and used to clock data into the DAC. The sequential addressing of the ROM is performed by two CD 4040 12-stage binary counters, IC2 and IC3. The gated 10-kHz clock pulses are fed to the first 12-stage counter, IC2. This counter addresses the first 12 bits (A0-A11) of the voice ROM. When IC2 overflows, a pulse is sent to the clock input

FIGURE 1



Complete schematic for the digitized voice ID'er.

of the next counter IC3, which handles the remaining address bits A12-A16.

There are two popular ROMs suitable for this circuit, the 27256 32K by 8 ROM and the 27512 64K by 8 ROM. At a sampling rate of 10 kHz the 27256 gives 3.2 seconds of voice; the 27512 delivers 6.4 seconds. These chips cost about $7 and $15, respectively.

The 27256 requires 15 address bits, A0-A14. The 27512 needs 16 bits, A0-A15, to address all memory locations. Two jumpers provided in the binary counter chain accommodate these differences. Jumper JP1 is connected to pin 1 of the ROM socket. If you use a 27256 ROM, you must select JP1 to provide a +5 volt level on pin 1 of the ROM. With a 27512, JP1 must apply counter address bit A15 to pin 1 of the ROM. The remaining jumper, JP2, controls the reset lines of the binary counters and the start/stop latch. This jumper selects the run time of the circuit. If you are using a 27256, you must connect JP2 to address bit A15 of the counter chain. A15 goes high after 3.2 seconds of run time. A high level on the reset lines clears the counters and the start/stop latch.

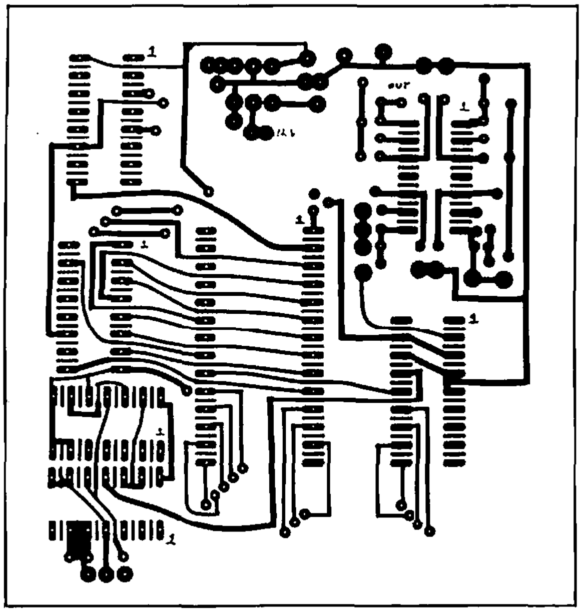
PARTS LIST

IC1	27256 or 27C256 300ns or faster EPROM-3.2 seconds of voice 27512 or 27C512 300ns or faster EPROM-6.4 seconds of voice
IC2	CD4040 binary counter
IC3	CD4040 binary counter
IC4	CD4013 dual flip flop
IC5	CD4011 quad nand gate
IC6	AD7224KN DAC from Analog Devices Corp., Two Technology Way, Box 280, Norwood, Massachusetts 02062-0280
IC7	LM-324 quad op amp
VR1	7805 +5 volt regulator
VR2	7905 −5 volt regulator
R1	100-k 10-turn pot, top adjust
R2	20-k 1/4-watt carbon resistor
C1	600-pF (approximately) silver mica or disc capacitor
10 ea.	0.1-μF 25-volt monolithic by-pass caps: 2 for VR1, 2 for VR2, and 1 by-pass cap from Vcc to ground for each IC
8 ea.	0.012-μF 25-volt monolithic or mylar caps
4 ea.	0.0039-μF 25-volt monolithic or mylar caps
8 ea.	5.1-k 1/4-watt carbon resistors
4 ea.	10-k 1/4-watt carbon resistors

When using a 27512, connect JP2 to A16 of the counter chain, which goes high after 6.4 seconds of run time.

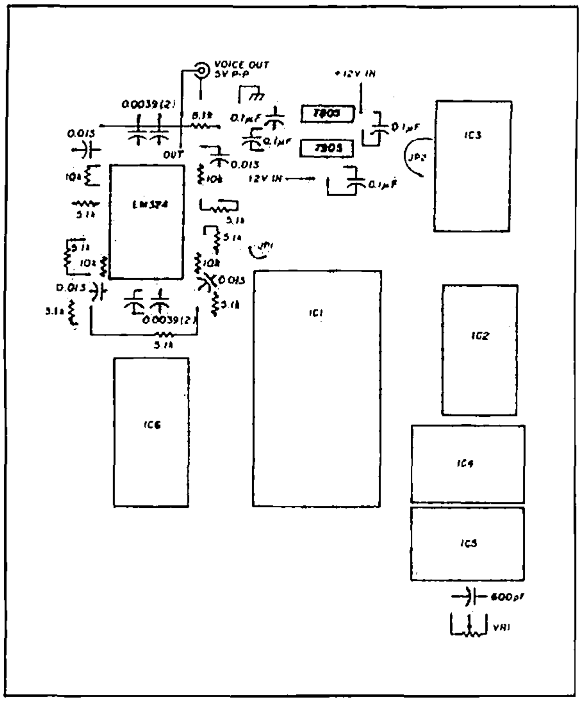
As the counters address each of the ROMs' memory locations sequentially, the 8-bit data output is clocked into the DAC. The DAC produces a voltage at pin 2 proportional to the magnitude of the binary number data point output by the ROM. A value of zero gives zero volts

FIGURE 2



Foil-side pc layout of the circuit.

FIGURE 3



Component placement for the component side of the pc board.

out, binary 10000000 gives 2.5 volts out and binary 11111111 gives 5 volts of output. This device can deliver 5 volts p-p of audio output, a substantial signal that needs to be reduced by a pot or fixed resistor network for most applications.

The power supply requirements are +12 Vdc at 40 mA and −12 Vdc at 15 mA. The + and − 12 Vdc supplies are used in the low-pass filters and are also regulated down to + and −5 Vdc. The +5 Vdc is used as the basic logic supply while the −5 Vdc is used as a reference for the DAC. See figs. 2-5 for pc board layouts and parts placement.

Bandwidth, sampling rate, and low-pass filters

When designing a digital voice storage device, pay careful attention to the interrelationship between audio bandwidth, digital sampling rate, and low-pass filter roll-off characteristics.

Audio bandwidth is usually determined by the frequency response of external electronics — in this case a typical narrowband FM voice channel. Assume a maximum frequency response of 5 kHz and you have just cast in concrete the minimum requirements for sampling rate and low-pass filter roll-off characteristics.

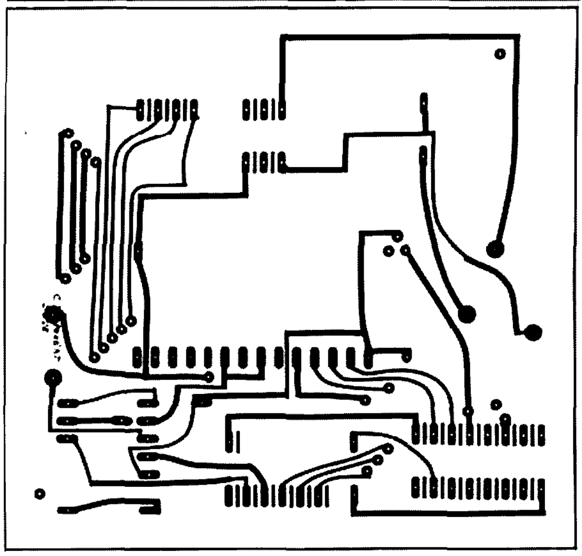
According to the Nyquist sampling theorem, a sine wave must be sampled a minimum of two times per cycle to be faithfully recreated. This project demonstrates this basic theorem. Because you've chosen 5 kHz as the maximum audio frequency, you must sample the signal at least 10,000 times per second and the low-pass filters must roll off at 5 kHz. Roll-off is usually measured in dB per octave; how much is needed?

When you violate the sampling theorem, a phenomenon known as aliasing results if you attempt to reproduce a frequency higher than the sampling rate allows. This makes the sine wave sound like a bucket of rusty bolts! Consequently, the low-pass filters must remove any detectable signal level in the frequency range above the Nyquist limit. The minimum detectable signal level is related to a property known as dynamic range, which is also expressed in dB and represents the amplitude range between the minimum and maximum reproducible levels.

This circuit uses an 8-bit DAC which gives 256 possible voltage level outputs with a maximum of 5 Vdc and a minimum of 5/256 = 0.0195 Vdc output. The formula for figuring dynamic range in dB, 20 log out/in, shows that this circuit has 20 log 5/0.0195 = 48 dB of dynamic range. Figure the dB roll-off for the filter. Remember that the low-pass filters must attenuate the nonreproducible audio frequencies (in this case above 5 kHz) below the minimum signal level out (0.0195 Vdc). By convention, roll-off is chosen to produce a maximum reproducible output of one half the minimum reproducible level, or 0.0195/2 = 0.0097 Vdc. The required roll-off is then dB = 20 log 5/0.0097 = 54 dB.

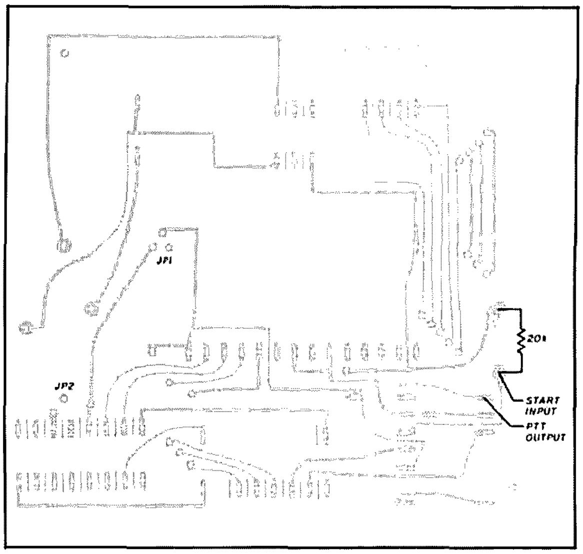
My primary concerns for the active filter design I chose for this project were price and parts availability. I didn't

FIGURE 4



Component-side foil pattern for the circuit.

FIGURE 5



Foil-side component placement guide.

rule out performance compromises in order to keep the construction simple. Active filter design is somewhat of a "black art" at best, even with the help of *The Active Filter Cookbook.* Design work often requires oddball, impossible-to-locate resistor and capacitor values, which I refused to accept.

The filter I settled on may not suit the taste of a mathematical purist but, at the cost of $1.00 each in parts, it can't be beat! I tested standard "off the shelf" 5-percent component values; they yielded very satisfactory results.

I needed a 54-dB roll-off, 5-kHz filter. The *Active Filter Cookbook* showed that a series of 5 second-order, equal component Sallen-key low-pass sections would fit the bill. Each second-order section gives 12 dB of roll-off. For economic reasons, I wanted to implement the entire filter on one LM-324 quad op amp. I designed a 4-section filter string which yielded about 48 dB per octave roll-off. The performance of the 48-dB filter was unacceptable so I changed the component values to the next higher 5-percent value. This, in effect, lowered the cut-off frequency of the filter below 5 kHz (a necessary compromise in order to give a 54-dB roll-off at 5 kHz). The final filter is pure simplicity: 2 resistor values, 2 capacitor values, and one 30-cent op ampl

Programming the voice ROM

You can program the voice ROM only with the aid of a personal computer. I plan to write another article on digital voice storage on the IBM PC. The hardware to implement voice storage on the PC is simple and provides the ability to directly program ROMs. The capability to store and retrieve voice on the PC offers a myriad of possibilities for automating the ham shack.

If you can't wait to find out how to program your ROM with the PC, I'll program it for you if you send me your EPROM, a good quality cassette recording of the voice passage you want programmed, and $10 to cover postage and handling.

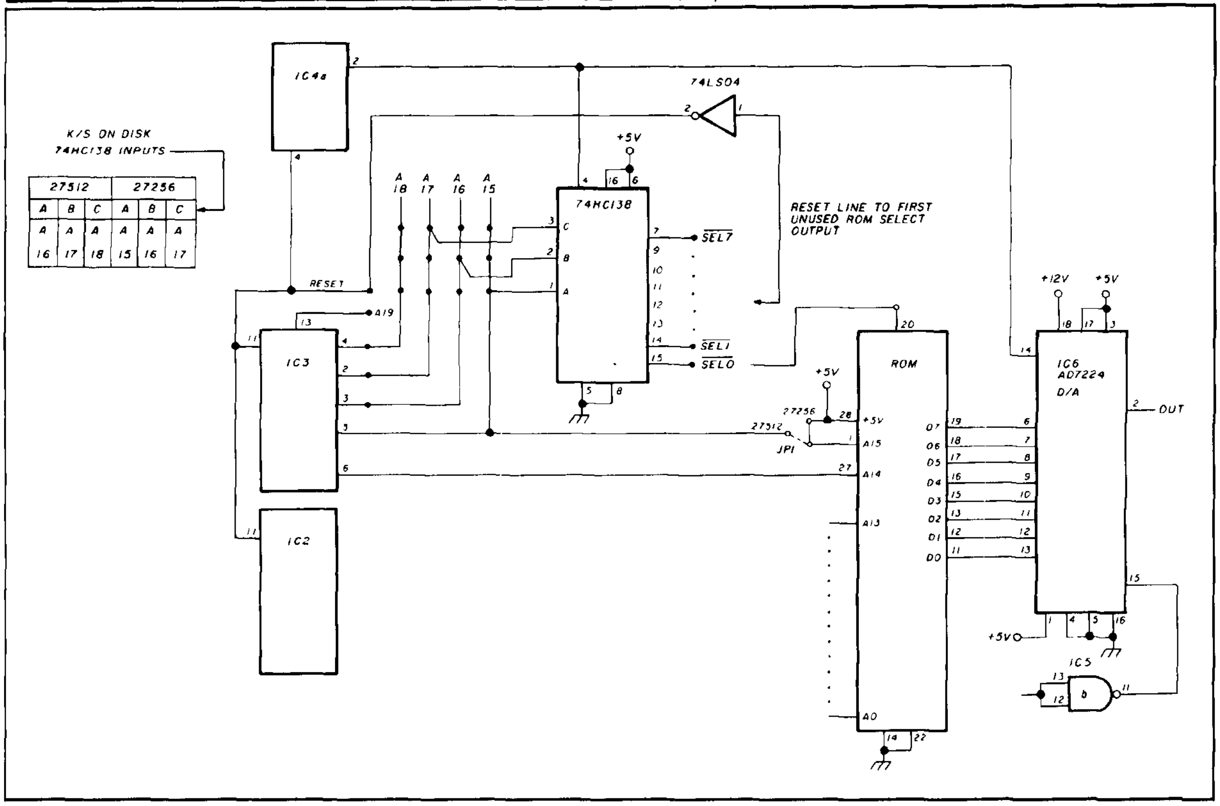
Modification of other ideas

This basic circuit has many uses beyond a repeater ID'er. You can prepare a canned message CQ caller for contests, create a beacon ID'er, or use the circuit as an instant touch-tone dialer for your favorite phone numbers. You can store any audio signal with frequency components under 5 kHz, including packet and SSTV transmissions. Because all the low-pass filter stages are DC coupled, the device can also store a serial TTL-level digital signal, provided that you keep the rate below 5K baud. I've used a similar unit to store digital test messages previously obtained from cassette tape in my professional work. Some useful changes you may wish to make include:

- Provide the ability to store two short messages in one ROM.
- Increase the length of storage time by adding more ROMs.

Both of these changes can be added easily. If you'd like to place two messages with a length of up to 3.2 seconds each into a 27512 ROM, simply select JP2 to provide a run time of 3.2 seconds and remove JP1. You can select two messages by way of an external ground applied to pin 1 of the ROM, if you place a 4.7-k resistor from pin 1 of the ROM to +5 volts. This divides the ROM space in half because pin 1 of the ROM is address bit A15. The 4.7-k pull-up resistor normally supplies a logic 1 to the A15 bit of the ROM; this selects the first message.

FIGURE 6



Schematic of the multi-ROM modification to allow expansion for up to 8 ROMs.

Select the second message by grounding A15 from an external source like a switch. I've used this scheme several times for repeaters by placing the normal callsign in the first half and a burglar alarm message in the second. I control the choice of messages with a switch on the door of the repeater building.

You can increase the length of the stored message by adding extra ROMs. All you need is an additional decoder chip to select them in sequence. Each additional ROM is wired in parallel with the first one, except for the chip select line pin 20 which is tied to one of the decoder outputs. Pin 22 of all ROMs must go to ground.

One 74HC138 octal decoder allows expansion of up to 8 ROMs; more than this will require extra buffering for the counter address bits. Using 27512 ROMs will give a maximum of 51.2 seconds of voice; 27256 ROMs will give you 25.6 seconds. When you use an extra decoder, the reset signal is derived from the next unused ROM select output of the decoder. For example, assume that you need a circuit containing 5 ROMs. The 74HC138 decoder has 8 outputs labeled from 0 to 7. Ouput 0 would go to the first ROM, output 1 to the second ROM, output 2 to the third, output 3 to the fourth, and output 4 to the fifth and last ROM. Output 5 of the decoder goes low after the last ROM is triggered, so output 5 must be inverted and used as the reset signal for the run/stop latch and the binary counters. (See **fig. 6**.)

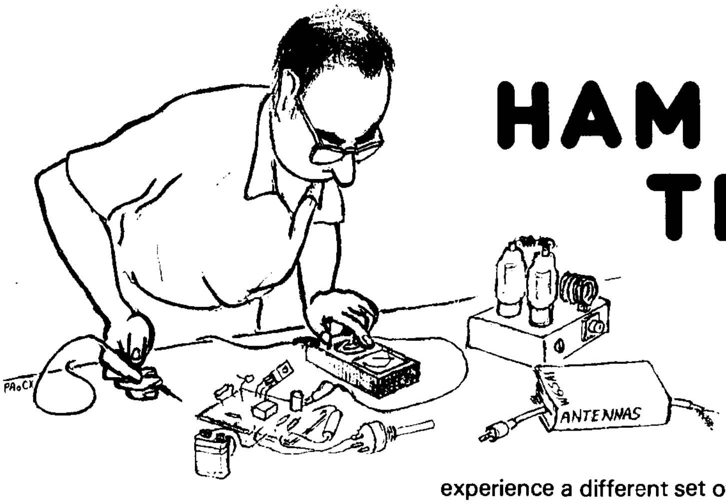
I hope I've helped give you a basic understanding of digital voice storage principles, and that you're eager to apply this device to your own projects. With a little ingenuity and logic you can modify the circuit to meet your own needs. Next time I'll discuss adding voice to the IBM series of computers and clones and the PROM programming procedure.

Article A **HAM RADIO**

A circuit board and parts kit are available from the author for $50.00 (ROM not included). Price includes one free programming of a ROM.

DECEMBER WINNERS

Congratulations to J.H. Defriend, WD6DTD, our December sweeps winner and W.C. Cloninger, Jr., K3OF, author of December's most popular WEEKENDER — "Get the Most from Your NiCds." Both will receive a handheld radio. To enter for February's drawing, send in the evaluation card bound into this issue, or submit a WEEKENDER project. You could be our next winner! *Ed.*



HAM RADIO TECHNIQUES

Bill Orr, W6SAI

"Son of Woodpecker," or, more of what we don't need!

The good news is that the sunspot cycle is rapidly rising and the MUF is increasing. Ten meters is now a *real* DX band. The bad news is that the rising MUF has revealed some noxious interference in the Amateur bands, and it's bound to get worse before it gets better.

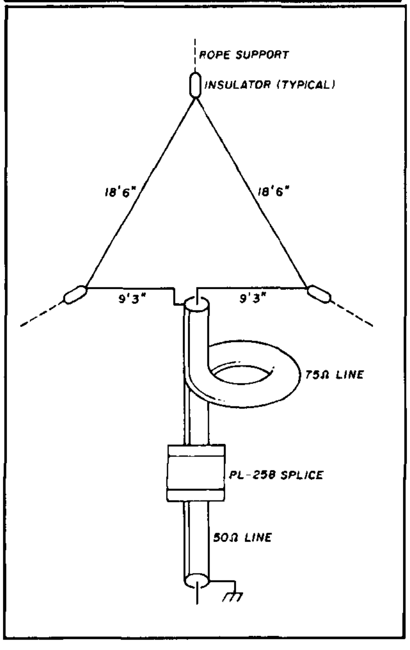
The interference I'm referring to is the "son of Woodpecker" radar signal in the 12-meter band. This buzzing source of interference is centered around 24.95 MHz and seems to be missile-tracking radar. It has a high repetition rate and sounds like a bumblebee. The signal peaks during the afternoon hours, indicating it's to the west of the Continental United States. When propagation is good, the buzzing noise blankets a large portion of the 12-meter band.

Direction-finding exercises have spotted the radar in the vicinity of Lake Baikal, and south of the city of Ulan-Ude, Siberia. I don't know if the radar runs continuously; I've only heard it at those times of the day when the MUF is high enough to support a propagation path between Central Asia and the United States. Unfortunately, the radar signal will become more disruptive as the MUF rises. And when the radar is absent, the "Woodpecker" takes over! What's next?

"Quickie" antennas for 18 MHz

It's fun to get on a new band and experience a different set of operating conditions. When the 24-MHz band was opened for general Amateur use, I found this band's propagation modes quite different from those on either the 21 or 28-MHz bands. As more Amateurs gain experience on 18 MHz, they'll find the propagation different from that on 14 or 21 MHz. I have monitored 18 MHz for years and have run transmissions using an experimental license (KM2XDW). Propagation experiments with the Cocos-Keeling Islands and India show that 18 MHz will quickly earn a reputation as a first class DX band!

FIGURE 1



Delta loop for 18 MHz. Coax transformer is 9 feet long, plug tip to plug tip. It's wound into a coil about 6 inches in diameter.

You can't do much on any band without an antenna. Here are several "quickie" antennas specifically for 18 MHz that are easy to build and put into service. They're designed to be hung from a yardarm on an existing tower. Because these antennas have their own feedlines, you don't need to disturb anything in the primary antenna system. The tower doesn't affect their operation, and the wire antennas don't interact with the antenna atop the tower.

The 18-MHz delta loop

The delta loop in **fig. 1** is a good "first" antenna for 18 MHz. It has a slight gain over a dipole and is very "user friendly." The feedpoint impedance of the loop is about 120 ohms. Use a 75-ohm quarter-wave transformer to provide a reasonable match to a 50-ohm coax line. The transformer is wound into a coil to choke off RF currents that might flow on the outside of the coax shield.

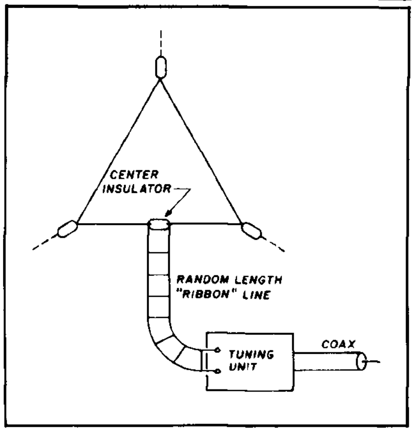
The feedpoint of the loop terminates in an SO-239 coax connector mounted on a small insulator plate. The transformer has PL-259 plugs on both ends. Make the splice between the transformer and the 50-ohm line with a PL-258 splice adapter. After making the connection, weatherproof the plugs and adapter with coax tape or heat-shrink tubing.

The loop is supported at the apex and the side insulators are tied off to objects nearby. The radiation pattern is similar to that of a dipole and is horizontally polarized.

A multiband version of the delta loop

You can operate the delta loop on the 18, 21, 24, and 28-MHz bands if

FIGURE 2



Balanced line feed with antenna tuning unit at station permits multiband operation of delta loop shown in *fig. 1*.

you feed it with a two-wire balanced line as shown in **fig. 2**. Transmitting-type 300-ohm ribbon line is satisfactory. You can also use open-wire style line. Match the line to a coax feed system by way of an antenna tuner (ATU or Transmatch) located at the station.

If you have difficulty loading the antenna on a band, change the length of the line between the antenna and the ATU. There is a standing wave on the line, and a particular line length may present an unacceptable load to the tuning unit. To solve this problem, add a few feet of line (a foot at a time) until you get a satisfactory match.

The bi-square array for 18 MHz

The diamond-shaped bi-square beam is much larger than the delta loop, but provides about 3-dB gain. This is a great antenna to try if you have the space. It's shown in fig.3.

The loop is a half wavelength on a side and open at the top. The feedpoint impedance at the bottom of the loop is about 2900 ohms; I use a two-wire 600-ohm quarter-wave stub to provide a more reasonable impedance value of about 122 ohms. Match it to a 50-ohm coax line by adding a quarter-wave transformer made of 75-ohm coax. Wind the 75-ohm line into a coil about 6 inches in diameter to reduce RF currents flowing on the outside of the coax. Under these conditions, the SWR on the transmission line is less than 1.2:1 across the band once the antenna is adjusted for resonance.

Tuning the antenna

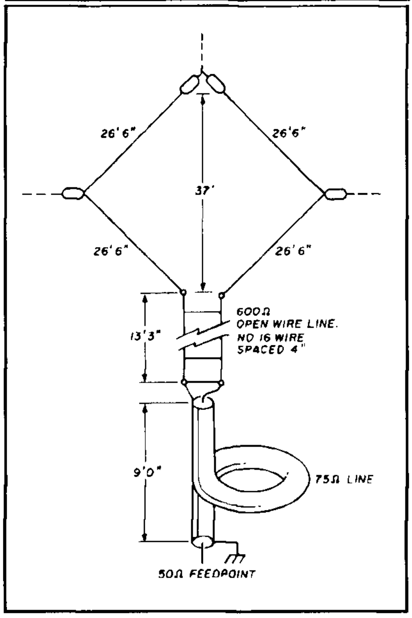
Resonate the loop and stub to 18.1 MHz with a dip meter. Temporarily close the stub at the bottom using a movable short with a 1-turn loop in the middle. I made mine with two copper alligator clips so I could move it up and down the stub a few inches. I adjusted the position of the short until I achieved antenna resonance with the dip meter, as monitored in a nearby receiver. As soon as you find the resonance, remove the short and place an SO-239 coax receptacle across the bottom of the line.

You'll need to waterproof the coax receptacle and all plugs and splices in the system. It's imperative to use coax tape or other weatherproofing compounds to keep water out of the line.

An extended dipole for 18 and 28 MHz

The extended dipole in **fig. 4** will

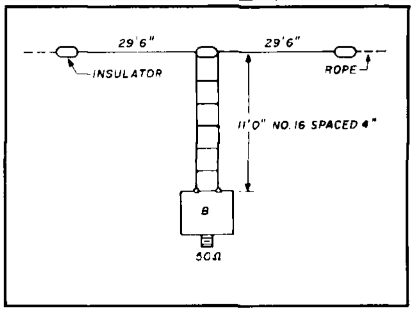
FIGURE 3



"Bi-square" beam provides a bi-directional pattern and about 3-dB gain over a dipole. Note that top of loop is open.

work on the 18 and 28-MHz Amateur bands. I discussed the theory behind this antenna in my April, 1987 *Ham Radio* column. The antenna consists of two extended half waves in phase on 18 MHz, fed by an open-wire matching stub. The total wire length of antenna and stub on 10 meters is about 2-1/2 wavelengths. You can achieve a good resonance on both bands. The feedpoint impedance is close to 50 ohms.

FIGURE 4



Dual-band dipole is fed with open-wire section and 1:1 balun (B). Antenna may be mounted in inverted-V configuration.

The antenna presents a typical dipole radiation pattern on 18 MHz; on 28 MHz the pattern has a cloverleaf shape.

Use a 1:1 balun at the feedpoint or coil the coax line into a 5-turn RF choke, as described for the previous antenna.

A trap dipole for the 18 and 24-MHz bands

This simple trap antenna covers the 18 and 24 MHz bands and makes an ideal companion to a tribander beam. The two antennas cover all bands between 20 and 10 meters at the flick of a coax switch.

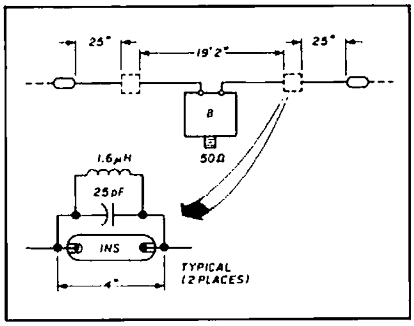
A practical design is shown in **fig. 5**. The trap is designed around a 25-pF 5-kV ceramic capacitor. You can find some of the older Centralab-type 850 capacitors at flea markets. High Energy Corporation, Lower Valley Road, Parkesburgh, Pennsylvania 19365, manufactures new capacitors. The coil is made of Barker and Williamson coil stock. The coil-capacitor com-

bination is mounted to a short ceramic insulator, as shown in the illustration.

Before placing the traps in the antenna, check their frequency with a dip meter and a calibrated receiver. The design frequency is 24.95 MHz. Place the trap in an area free of metallic objects and couple it loosely to the dip meter. Note the resonant frequency; it should be within ± 100 kHz, of the design frequency.

One end turn of each trap can be broken free of the coil bars, and moved about or trimmed to set the exact point of resonance. Do this after attaching the trap to the insulator — the capacitance across the insulator influences the resonant frequency of the trap to a degree.

FIGURE 5



Trap antenna for 18/24 MHz. Trap is mounted across ceramic insulator. Coil consists of 12-3/4 turns, no. 20, 5/8-inch diameter, 16 turns/inch. (Barker and Williamson 3007.)

You can trim the end sections "on the nose" by erecting the antenna in the clear about 6 feet above the ground. Place a half-turn coil across the center insulator of the antenna and check the 18 and 24-MHz resonances with a dip oscillator. Removing 1 inch on each side of the center sections moves the resonant frequency 100 kHz at 24.9 MHz. You must adjust the inner sections before resonating the tip sections. I cut my tip sections about a foot long and twisted the extra length back on the antenna. I took off the extra length upon reaching the right resonant point at 18.1 MHz. The SWR across either band will be less than 1.5:1 when the antenna is in place.

A really simple shortwave receiver

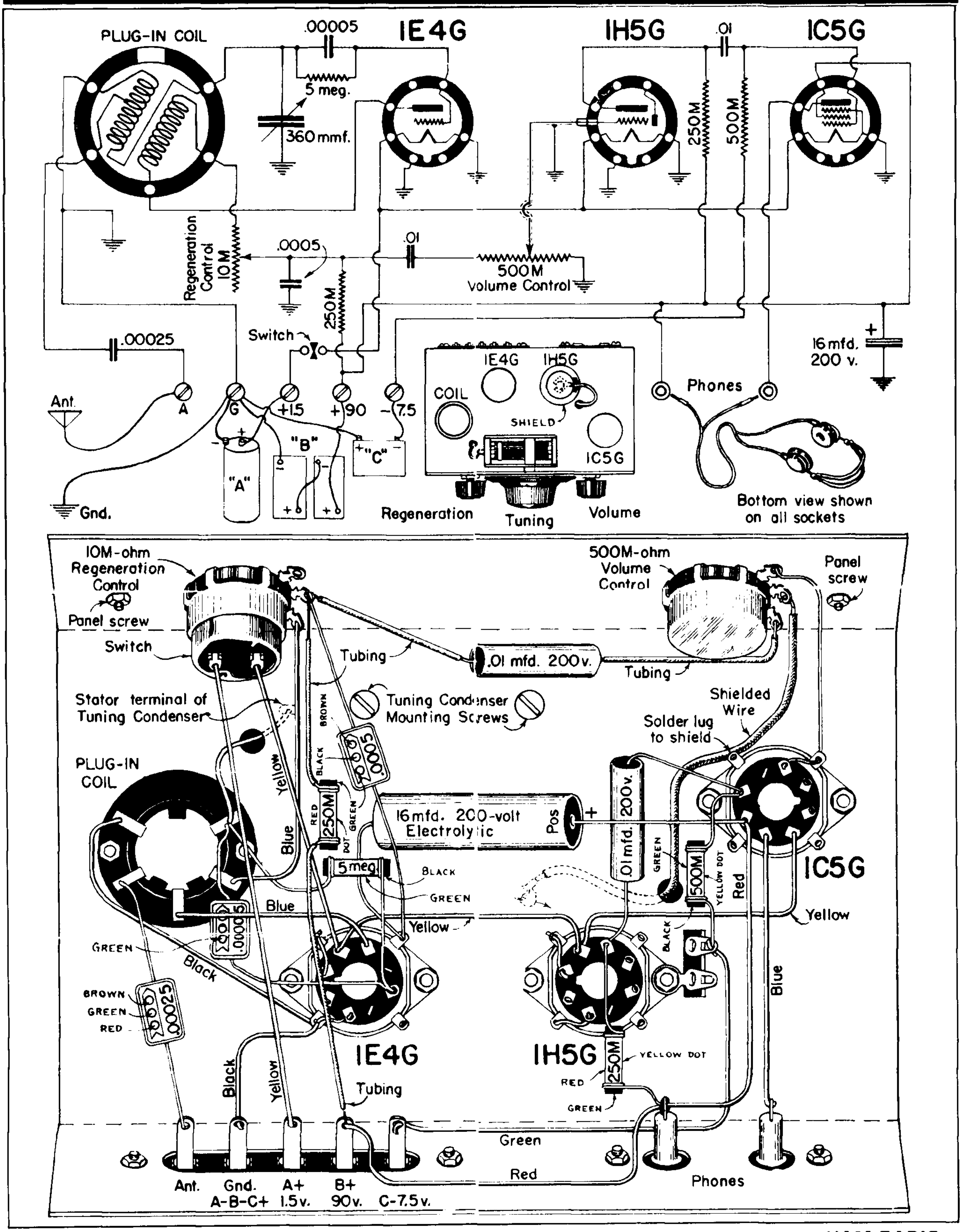
Are you tired of modern high-tech radios? Do you yearn for the good old days when radios had only a couple of knobs? Well, fig. 6 shows the receiver for you. The radio uses only three tubes and runs on inexpensive A, B, and C batteries. I've included a layout of the aluminum chassis to help you build this little set. You say your local ham store doesn't carry plug-in coils, radio tubes, tube sockets, tuning capacitors, etc? Well, what does it carry?....Oh!

The W6SAI "Dead Band" contest

I salute my readers who spotted the quotation from *Catcher in the Rye*, by J. D. Salinger. The remark was made by the anti-hero, Holden Caulfield. Kudos to the following with a special salute (*) to those who really know their rye:
Tony Emanuele, WA8RJF; Lou Axeman, N8LA (*); Bill Wootton, WO7J; Steve Buol, KB0BDS; David Raskin, W5TYL; Jim Fox, N7ENI; Jack Starin, WF8M; Bob Eslaire, W9UI/8; Larry Walsh, W5SMA; Martha Wilder, N3FZB; Phil Brandt, W3ELJ; Bruce Rossi, NF7J; Jim Lignugaris, N2IDV; Dick Olson, NS0W; Marty Johnson, W3YOZ (*); Marty Davidoff, K2UBC (*); Preston Douglas, WA2IFZ; Roger Leone, K6XQ; Serafino Conflitti, VE3LKN; Eric Nichols, KL7AJ; Bill Calderwood, K1CT; Roger Tobin, N1EYZ; and Frank Smith, W4EIN. Congratulations to all!

School is out and this is winter break. No quiz this month. Instead, I want to recommend a great book. It has nothing to do with Amateur Radio, but it's the best adventure story I've ever read. It covers territory from Vladivostok to Odessa in an exciting tale about two great men. *The Cowboy and the Cossack*, by Clair Huffaker was published by Trident Press, New York (1973). Unfortunately the book is out of print, but it's worth your time to check in a second-hand book store. This is a wonderful book to read when the band is dead!

FIGURE 6



Article B **Schematic of 3-tube regenerative receiver. Just the thing for the new Amateur!** **HAM RADIO**

THE WEEKENDER

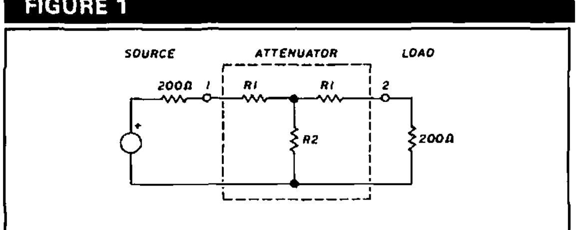
High-impedance rotary step attenuator

Need a step attenuator? I was building ladder crystal filters and wanted an attenuator to help in making the passband measurements. I only needed a few steps, and a rotary switch similar to one made by W9ERU[1] was more appealing to me than the laboratory type[2] with banks of slide switches. A 200-ohm impedance level is appropriate for the filters. But you can construct any impedance level by using resistors scaled to the values shown here.

Switch

You'll need a 3-deck rotary switch to select the proper resistors for the T-Network shown in **fig. 1**. My junkbox yielded a 7-position one. I selected attenuation values of 0, 3, 6, 12, 20, 30, and 40 dB as convenient values for my crystal filter work. You can duplicate these if your switch has 7 positions, or calculate the resistors for any other number of positions or dB values using the information at the end of this article. Tables of resistor values (50 ohms) also appear in recent editions of *The ARRL Handbook*.[3]

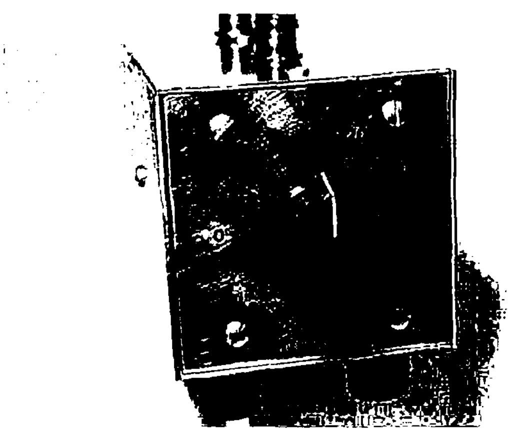
FIGURE 1



Schematic of the basic T-Network on which the step attenuator is based.

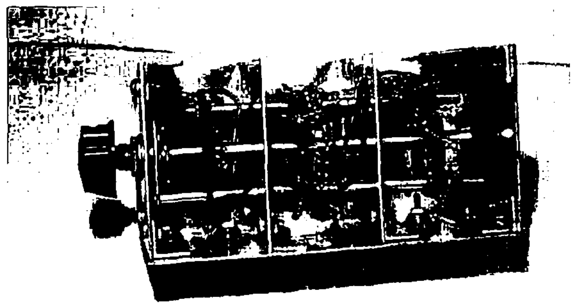
By John Pivnichny, N2DCH, 3824 Pembrooke Lane, Vestal, New York 13850

PHOTO A



Front panel view of the step attenuator. Note attenuation values labeled on the front.

PHOTO B



Internal view of the step attenuator showing partitions used for additional RF shielding.

Enclosure

You can mount the switch in a 2-1/2″ × 2-1/2″ × 5″ homebrew box. Sheet aluminum 0.05″ thick, cut on a metal shear makes a neat box. I also included two shield partitions (also 2-1/2″ × 2-1/2″) to prevent stray coupling between switch decks. One-half inch aluminum angle stock, 1/16″ thick, holds the sheet metal pieces together forming a rigid and rugged box. See **photos A** and B for details. Note that the bottom plate is exactly 2-1/2″ × 5″, but the top and sides are cut slightly wider (2-9/16″ × 5″) to provide proper overlap of the adjoining edges. I fastened four rubber feet to the bottom plate. As a finishing touch, I applied dry-transfer letters and India Ink to the front panel after buffing with emery paper. I used clear spray lacquer to protect the letters and keep them from rubbing off.

Resistors

The necessary resistance values for R1 and R2 in **fig. 1** are listed in **table 1**. The power rating is also important. For example, in the 3-dB position half of the input power

TABLE 1

Resistor values for R1 and R2.

dB	R1 (ohms)	R2 (ohms)
3	34	567
6	66.8	268
12	120	108
20	163.6	40.5
30	188	12.6
40	196	4

TABLE 2

Resistor values in *fig. 2*

	ohms	1/4-watt resistors (ohms)
Ra	34	68 P 68
Rb	34	15 S 18
Rc	53	100 P 110
Rd	43	22 S 22
Re	25	47 P 56
Rf	8	15 P 15
Rg	4	12 P 12 P 12
Rh	8.5	15 P 15
Ri	28	56 P 56
Rj	65	150 P 120
Rk	157	330 P 330
Rl	300	150 S 150

S = series connection
P = parallel connection

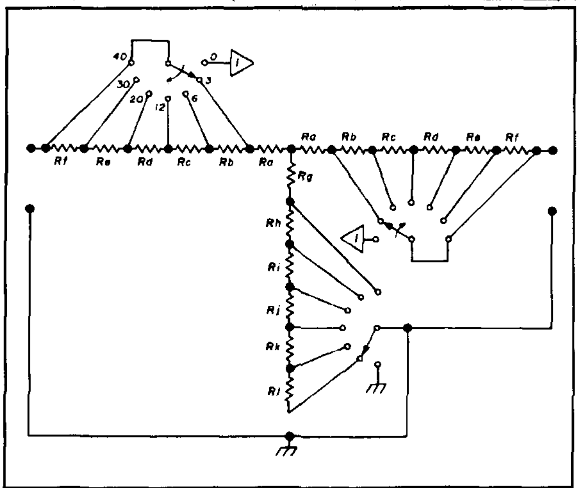
is delivered to the load and the other half must be dissipated by the resistors in the T-Network. At 6 dB, 75 percent of the power is dissipated in the T-Network; at 40 dB, only 0.01 percent goes to the load.

With power in mind, use a series connection of resistors so the power is shared. **Figure 2** shows the final schematic and **table 2** lists the series resistor values. These aren't standard values, so make a reasonable approximation to Amateur accuracy (± 2 percent or so) by selecting two nearly equal standard values and connecting them in parallel or series to obtain the values in **table 2**. (The 4-ohm value is made with 3 12-ohm resistors in parallel.)

I used 1/4-watt resistors as indicated in the last column of **table 2**. Each individual resistor of **fig. 2** can therefore dissipate 1/2 watt. A careful calculation of power shows that this attenuator handles up to a 20-volt RMS (56 volts p-p) input voltage, or 2 watts. At that level the 53-ohm resistor will dissipate almost 0.53 watt at 12 dB and greater positions. The remaining 1.5 watts is dissipated in the other resistors, all of which are safely below a half watt each.

Crystal filters can be damaged by excess voltage. I don't recommend putting 20 volts into one. This attenuator will easily handle the signal levels you normally encounter.

FIGURE 2



Schematic of the step attenuator using a 7-position 3-deck rotary switch.

Checkout

After completing the attenuator, make two tests to ensure that there are no wiring errors. First, attach a 200-ohm load to one of the connectors (I used two 390-ohm, 1-watt resistors in parallel). Measure the resistance at the other connector with your ohmmeter. It should read 200 ohms at all switch positions. Repeat this test with the connections reversed.

Second, apply a 20-volt DC *potential* at one connector with the load attached at the second connector. Read the voltage across the load at each switch position and compare it to **table 3**. As before, repeat this test with the connections reversed.

Conclusion

You now have a rotary step attenuator for crystal filter measurements. It's a handy accessory that takes only a weekend to build.

TABLE 3

Output voltage readings with 20 volts at the input

dB	volts
0	20
3	14.4
6	10
12	5
20	2
30	0.63
40	0.2

Appendix — resistor value calculation

Refer to **fig. 1**; the resistance looking into node 1 must be 200 ohms.

$$[(200 + R1) \,||\, R2] + R1 = 200$$

$$\frac{(200 + R1)\,R2}{200 + R1 + R2} + R1 = 200 \qquad (1)$$

after some algebra:

$$R1^2 + 2R2R1 - 200^2 = 0$$

by the quadratic formula:

$$R1 = -R2 \pm \sqrt{R2^2 + 200^2} \qquad (2)$$

reject the negative value and define:

$$P = \frac{(200 + R1)\,R2}{200 + R1 + R2}$$

then the attenuation is given by the voltage dividers:

$$\frac{V2}{V1} = \frac{200}{200 + R1} \cdot \frac{P}{R1 + P} \qquad (3)$$

The procedure for calculating resistor values is as follows:

- Pick a value for R2.
- Compute R1 using **eqn. 2.**
- Compute P.
- Compute attenuation V2/V1 using **eqn. 3.**
- Compute dB from $dB = -20 \log_{10}(V2/V1)$.

You can write a short BASIC program with any small home computer to perform these calculations. A for-next loop with values of R2 from 1-400 ohms will generate R2 values to the nearest ohm. Use additional loops in 0.1-ohm steps to calculate more accurate values.

Note: Not all versions of BASIC have the base 10 logarithm function. To convert from the base e natural logarithm to base 10, multiply the base e result by 0.43429.

References

1. Eugene A. Hubbell, W9ERU, "A Step-Type R.F. Attenuator," *QST*, vol. 43, no. 12, December 1959, pages 20-22.
2. Bob Shriner, WA0UZO, and Paul K. Pagel, N1FB, "A Step Attenuator You Can Build," *QST*, vol. 66, no. 9, September 1982, pages 11-14.
3. *The ARRL Handbook*, Newington, Connecticut, 62nd edition, 1985, page 25-44.

Article C **HAM RADIO**

THE L-MATCH

A useful tool for improving your SWR

By Robert C. Cheek, W3VT, 29 Center Drive, Briarcliffe Acres, Myrtle Beach, South Carolina 29572

How often have you carefully calculated the length of a dipole antenna, cut it to just the right length, used coax cable which should have given you a reasonably good match, and then found that the SWR just wouldn't go below 2:1? And how often did the SWR rise to an unacceptably high level in the phone portion of the band even though you had an acceptable match in the CW portion (or vice versa), especially on the 3.5 and 7-MHz bands? If your experience has been anything like mine, the answer is: "Almost always!" If you like to operate both phone and CW, the same experience probably applies to your Yagis on the higher frequency bands. You may have a good SWR in one segment of a band, but elsewhere it rises to a point where a modern transistorized rig automatically starts cutting down on power output.

Many modern transceivers have built-in automatic antenna tuners, and I suspect that's why we hear more on-the-air tuning these days. They are a lazy man's solution to poor SWR. Unfortunately, those already in contact with someone on the chosen tuning frequencies must continually pay for this practice.

Power amplifiers usually don't have built-in tuners. Even if you tune your amplifier into a dummy load first, you must touch up the tuning with your antenna connected if the SWR is more than about 1.3:1 (another excuse for on-the-air tuning). Wouldn't it be much better to have an SWR close to 1:1 in both the phone and CW segments of the band so all your tuning could be done with a dummy load? Then you could switch your rig to the antenna without further tuning and unnecessary QRM.

A universal antenna tuner with predetermined and carefully marked settings could solve these problems, if you had the patience to reset it each time you made a substantial frequency change. But a simpler, more compact, and less expensive answer to these and many other impedance-matching problems is a well-known, old-fashioned, but infrequently used technique — the L-match. This application of the L-match is mentioned very briefly in the *ARRL Antenna Book*.

I use several fixed L-match configurations; all are built into miniboxes (although I sometimes run 1500 watts PEP). One of these is permanently inserted at the input end of several different coax cables, each feeding a different antenna. Some have a switch to by-pass the network for operation on a frequency range over which the SWR is acceptably close to 1:1. The switches are within reach of my operating position.

This article shows derivations of formulas for calculating the reactances, and corresponding capacitance and inductance values, needed in an L-network to make a mismatched line appear to have 1:1 SWR. This makes it look like a desired pure resistance (normally you'll want 50 ohms) to the transmitter at a specified frequency. I've included a program in GW-BASIC for IBM PC compatible computers, but you can also use the formulas and a calculator with a square-root function to make the necessary calculations. The program selects all the possible capacitance and inductance configurations that provide a match for a given case and does the necessary calculations for each configuration. (There may be as many as four different combinations that will do the job for one set of conditions.) The program checks its own results by calculating independently the input impedance of the line with the matching network added, and comparing it to the desired input resistance. I've described a few actual networks to show the design procedure, some possible construction approaches, and the "before" and "after" results.

Some application notes

The L-match is more versatile than is generally recognized and understood. Theoretically an L-type network consisting of only two elements (a shunt element and a series element) can match any two complex impedances to each other at a given frequency, as long as the elements are perfectly lossless. Of course you can't have

either inductors or capacitors of infinite "Q", and for applications involving very large impedance transformations there are some limitations. But in the application discussed here, the impedances to be matched aren't different enough to present a problem.

There are other limitations that should be considered in this application. One limitation is that although an antenna tuner (or any other matching device at the transmitting end of a coax line) may make the transmitter see a 1:1 SWR, it doesn't in any way affect the SWR in the line beyond the device. Losses in a mismatched line are higher than if the impedance were matched at the antenna end. Fortunately, this effect isn't serious if you use good quality cable in good condition — unless you have lines several hundred feet long at the higher frequencies (28 MHz or higher).

As SWR departs from the ideal 1:1, the voltage and the current at some points on the line become greater than those that exist uniformly on a matched line at the same level of power transfer. For example, at an SWR of 4:1 the voltage and current at some places along the line will be twice what they would be if the line were matched at the antenna end with the same power going into the antenna. Pay attention to the voltage rating and the current-carrying capacity of the line. The 5000 volt rating of the RG-213 cable gives plenty of margin for poor SWR, compared with the 275 volts present at 1500 watts when the line is matched. A cable connection is far more likely to break than the cable itself if the voltage is excessive at a connection point. The current rating (imposed by the possibility of cable damage due to internal heating) is a more important limitation. The same cable is rated at 3500 watts at 10 MHz, or about 8.4 A when the SWR is 1:1. With a 4:1 SWR, the current will reach about 11 A at 1500 watts. In our intermittent types of service, peak currents of this level at widely separated points on the line should cause no damage. But there's probably some cause for concern somewhere not too far above 4:1 SWR and above 10 MHz. These considerations apply to any input-end matching system.

To summarize: If you are running maximum legal power and using RG-213 or similar cable, I *do not* recommend that you use an antenna tuner or any other matching device at the transmitter end of a line to correct an SWR that exceeds 4:1. If your SWR is higher than that, you need to do some work on the antenna or the matching device at its end of the line!

The bandwidth of acceptable SWR is another important thing to consider for this application. The higher the SWR on the line, the greater will be the effect of the individual elements in the matching network at a specific frequency. This means that the effects of frequency variations will be more pronounced, and the bandwidth over which reasonable SWR correction can be obtained will be more limited. However, the overriding bandwidth effect will usually be that caused by the variation of the input impedance of the line. This is due to changing load (antenna) characteristics and the changing electrical length of the line as the frequency is varied. Because each antenna system has its own characteristics, it's impossible to generalize about this problem. I've found that with most antennas, the frequency ranges over which the SWR is acceptable are about the same with the networks in operation as they are in different parts of the same bands where the lines are properly matched. One exception to this is my 40-meter Yagi, on which the parasitic elements are optimized for the CW band. The self-resonant frequency of the director is quite near the upper end of the phone band, and the input impedance of the line varies rapidly as I approach that end of the band. So with a matching network designed to optimize the SWR in the phone segment, the bandwidth of acceptable SWR is slightly less than the entire phone band.

The calculation of the network elements' reactances, whether by the formulas or the computer program, first requires that the input impedance (resistance and reactance) of the line be measured fairly accurately. Do this at the frequency for which the SWR is to be corrected. To make the measurement you'll need either an RF impedance bridge (like the one described in the *ARRL Handbook* and the *ARRL Antenna Book*) or a high-quality noise bridge calibrated for reactance measurements. I've used both with good results, but you can use the noise bridge only when the frequency of interest is very quiet, so that the null is unmistakable.

Make the measurement at the exact point in the line where the matching network is to be inserted. Use any convenient length of cable from the network back to the transmitter. This cable length can be changed, but the length of the line between the antenna and the matching device must remain the same.

Formulas for calculating the L-match

An L-network consists of just two elements — a series element and a shunt element. The shunt element may be on the load side or the generator side of the series element, but there are certain conditions under which only one of these configurations provides valid solutions.

In the derivation of the formulas (shown in **figs.** 1 and **2**), the desired impedance as viewed from the generator (transmitter) side is designated as R_0. The derivations assume that this impedance is to be purely resistive. The impedance of the load (the input to the coaxial cable terminated at its far end by the antenna) will have a resistive component (always positive), designated as R_a, and a reactive component (positive, negative, or in some cases zero), designated as X_a. The shunt element of the network is designated as X_{sh}.

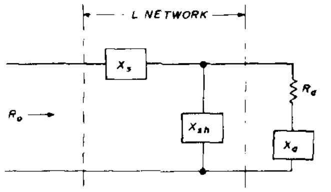
Figure 1 shows the derivation of the formulas for the

first configuration in which the shunt element is on the antenna side of the series element. The transmitter is connected through the series element to the parallel combination of the shunt element and the load. The real components are extracted to form one equation from the complex algebra expression of this circuit. The imaginary components that remain (with the "j" operators dropped) constitute a separate equation. The first equation is solved to get a formula for X_s, the series element. This formula can't yet be used for final calculation of X_s because it involves X_{sh}, which is still unknown at this point.

Next the equation derived from the imaginary components is solved for X_{sh}. The expression for X_s is substituted where X_s appears in this equation. This gives a quadratic equation for X_{sh}, which is solved by the quadratic formula to give X_{sh} in terms of the known resistances and reactances. After X_{sh} is calculated, X_s can be determined from the first formula.

There are always two mathematical solutions for X_{sh}, as indicated by the plus and minus signs before the square root. However, the configuration doesn't have a valid (real) solution for combinations of the variables that lead to a negative quantity under the square root sign. In such cases, the configuration is not physically realizable and can't be used.

FIGURE 1



R_o, the impedance seen by the transmitter, is the parallel combination of $R_a + jX_a$ and jX_{sh}, in series with jX_s:

$$R_o = jX_s + \frac{jX_{sh}(R_a + jX_a)}{R_a + j(X_a + X_{sh})}$$

This can be restated as:

$R_oR_a + j(R_oX_a + R_oX_{sh}) = jR_a X_s - X_aX_s - X_sX_{sh} + jR_aX_{sh} - X_aX_{sh}$

From the real terms:

$$X_s = -\frac{R_oR_a + X_aX_{sh}}{X_a + X_{sh}}$$

From the imaginary terms, substituting the above for X_s: $(R_o - R_a)X_{sh}^2 + 2R_oX_aX_{sh} + (R_oX_a^2 + R_oR_a^2) = 0$

Solving for X_{sh} by the quadratic formula:

$$X_{sh} = \frac{R_oX_a \pm \sqrt{R_o^2X_a^2 + (R_a - R_o)(R_oX_a^2 + R_oR_a^2)}}{R_a - R_o}$$

For either configuration, if X_s or X_{sh} (denoted as X below) is positive, calculate its inductance as follows, with F in kHz:

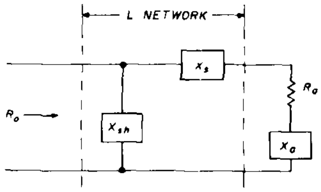
$$L = \frac{1000X}{6.28F}\ \mu H$$

If X_s or X_{sh} is negative, calculate its capacitance as follows:

$$C = \frac{-10^9}{6.28FX}\ pF$$

Derivation of formulas for first configuration.

FIGURE 2



R_o, the impedance seen by the transmitter, is jX_{sh} in parallel with the series combination of $R_a + jX_a$ plus jX_s:

$$R_o = \frac{jX_{sh}(R_a + jX_a + jX_s)}{R_a + j(X_a + X_s + X_{sh})}$$

This can be restated as:

$R_oR_a + jR_o(X_a + X_s + X_{sh}) = -X_aX_{sh} - X_sX_{sh} + jR_aX_{sh}$

From the real terms:

$R_oR_a = -X_aX_{sh} - X_sX_{sh}$

or

$$X_s = -\frac{R_oR_a}{X_{sh}} - X_a$$

From the imaginary terms, substituting the above for X_s:

$(R_o - R_a)X_{sh}^2 - R_o^2R_a = 0$

Solving for X_{sh} by the quadratic formula gives:

$$X_{sh} = \pm R_o\sqrt{\frac{R_a}{R_o - R_a}}$$

Use the formulas for L and C as given in **fig. 1**.

Derivation of formulas for second configuration.

In **fig. 2** an identical procedure is used to derive the formulas for the second configuration, in which the shunt reactance is on the transmitter side of the series element. Again there are two mathematically valid solutions, and again there are combinations of variables for which there is no real solution. This configuration has real solutions only when R_a, the resistive component at the cable input, is less than R_0, the resistive load to be seen by the transmitter.

Despite the range of variables for which there is no usable solution in one or the other of the configurations, one of them always *has a real solution for* a given set of variables. In many cases both configurations are applicable, and for such cases there are four different possible combinations of reactive elements to choose from.

Generally, the best choice is the one involving the most practical values of inductance and capacitance. From the standpoint of physical size and losses, a lower value of inductance is preferable to a higher one. For harmonic attenuation, a combination using shunt capacitance and series inductance is preferable to one using shunt inductance and series capacitance.

The L-match computer program

The computer program (**fig. 3**) uses the formulas derived in **figs. 1** and **2** to compute the reactance values and corresponding capacitances and inductances in all the usable configurations for a given set of conditions. The program is written in GW-BASIC and should run successfully on any IBM-compatible personal computer.

The two configurations are examined in turn. The first to be examined is the one with the shunt reactance on the antenna side of the series reactance (the first configuration). An *error-trapping routine detects situations* in which the square-root calculation would involve a negative quantity, or where there is an attempted division by zero. In these situations there is no real solution for the configuration. The error-trapping routine reports this fact and routes the program to the calculation of the second configuration, for which similar error trapping is provided.

As the reactances for each case are determined, a subroutine (lines 3000 through 3110) checks their values by using them to calculate and display the impedance seen by the transmitter with the matching network in place. Line 3080 compensates for small rounding and computing inaccuracies (up to 0.1 percent) in comparing the resistive component of the result with the desired resistive load. In the result, line 3090 rounds to zero any final reactive component of less than 0.1 percent of the resistive component. If single-precision computation were used, these inaccuracies (which occur primarily in the checking routine) might exceed the limits in rare cases where the computations involve small differences in large quantities. All computation is done in double precision. But the checking routine is correspondingly accurate only if the program is run with BASIC loaded with the double-precision transcendental math package (BASIC/D) that improves the precision of the trigonometric functions used. If you don't use BASIC/D, a reactive component exceeding 0.1 percent of R_0 (but still negligible) may appear in rare cases in the check result.

In any case, results stated in single precision are more than adequate for your purposes. So all computed values to be displayed are converted to single-precision numbers before they are presented.

Some practical L-network matching devices

In the networks I'll describe, all parts except the miniboxes are from flea markets or my junkbox.

I avoid using variable capacitors because they're bulky, expensive, and hard to find. Also, once you've determined the capacitance, no further change is required in this application.

When winding the coils, I estimate the number of turns required from the formulas given in the *ARRL Handbook*, and then wind about 20 percent more. With the network completed (except for final connection of a flexible lead to one end of the coil), I install the device in the line and connect it directly at the output of my SWR meter. Using very low power at the design frequency, I move the lead across the coil to find the tap point that gives minimum SWR. The minimum is usually quite close to 1:1; if it's not, I may need to do some trimming of the capacitance by adding small values in parallel with it or changing to a slightly lower value. When I find the proper combination, I solder the tap and clip off most of the unused coil turns. Before removing all the unused turns, I check the final combination with the box cover installed. Sometimes the coil inductance is lowered by the proximity of the shielding, and the final coil may require an additional turn or two to provide the same inductance as with the cover off.

I have also used manufactured coils (e.g., Miniductors) with equal success. The *ARRL Handbook* also gives information for estimating the inductance of these coils for different diameters and turns per inch.

160-meter dipole

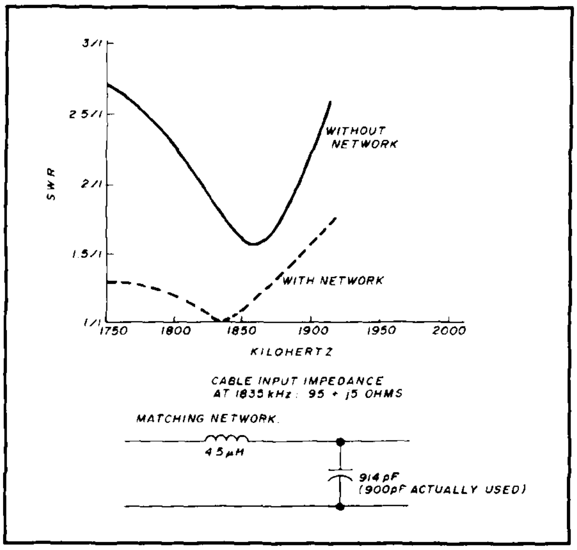
Figure 4 shows the original SWR curve at the input end of the 50-ohm line to my 160-meter dipole. The minimum SWR is 1.6:1 at 1860 kHz. I normally confine my 160-meter operation to the CW and DX portions of the band (1800 to 1850 kHz). I do most of my operating around 1835 kHz. The SWR on this frequency is 1.8:1. It's actually impossible to tune the amplifier properly with this antenna, because the range of its loading capacitor is severely limited by the heavy padding it requires on this band. As a result, it runs out of range very quickly as the load impedance departs from 50 ohms resistive.

FIGURE 3

```
1000 RO=0:RA=0:XA=0:XSH=0:XS=0:DEFDBL A-Z
1010 CLS:INPUT"FREQUENCY (KHZ)";F
1020 INPUT "DESIRED LOAD RESISTANCE";RO
1030 INPUT "RESISTANCE LOOKING TOWARD ANTENNA";RA
1040 INPUT "REACTANCE LOOKING TOWARD ANTENNA";XA:PRINT
1050 IF RA=RO THEN PRINT TAB(5)"NO SHUNT REACTANCE REQUIRED":XS=-XA:PRINT:GOSUB
2030:GOTO 4500   'Special Case. Calculate XS and go directly to end.
1060 PRINT "WITH SHUNT REACTANCE ON ANTENNA SIDE OF SERIES REACTANCE:"
1070 ON ERROR GOTO 4000   'Set up error trapping for next calculation
1080 XSH=((RO*XA)-(SQR(((RO^2*XA^2))+((RA-RO)*((RO*XA^2)+(RO*RA^2))))))/(RA-RO)
  'Calculate shunt reactance for first case, first configuration
1090 GOSUB 2000:GOSUB 3020   'Calculate series element, display results and
   check them
1100 PRINT"OR:";
1110 ON ERROR GOTO 4010   'Set up error trapping for next calculation
1120 XSH=((RO*XA)+(SQR(((RO^2*XA^2))+((RA-RO)*((RO*XA^2)+(RO*RA^2))))))/(RA-RO)
  'Calculate second case, first configuration
1130 GOSUB 2000:GOSUB 3020   'See remarks for 1090
1140 PRINT:PRINT "WITH SHUNT REACTANCE ON TRANSMITTER SIDE OF SERIES REACTANCE:"
1150 ON ERROR GOTO 4020   'Set up error trapping for second configuration
1160 XSH=RO*(SQR((RA)/(RO-RA))):XS=-(RO*RA/XSH)-XA   'Calculate first case, 2nd
   configuration
1170 GOSUB 2010:GOSUB 3000   'Calculate inductance and capacitance, display
  results and check them
1180 PRINT"OR:";
1190 XSH=-XSH:XS=-(RO*RA/XSH)-XA   'Calculate second case,second configuration
1200 GOSUB 2010:GOSUB 3000   'See remarks for 1170
1210 PRINT:GOTO 4500
2000 XS=-((RO*RA)+(XA*XSH))/(XA+XSH)   'Calculate series reactance, first
  configuration
2010 X=XSH:IF X>0 THEN GOSUB 2510:X!=X:PRINT TAB(5)"Shunt Inductive Reactance is
 ";X!;" ohms (";L!;CHR$(230);"H)"   'If shunt reactance is inductive, go calcu-
  late inductance and display both in single precision
2020 IF X<0 THEN GOSUB 2500:X!=X:PRINT TAB(5)"Shunt Capacitive Reactance is ";X!
;" ohms (";C!;"pFd)"   'If shunt reactance is capacitive, go calculate capaci-
  tance and display both in single precision
2030 X=XS:IF X<0 THEN GOSUB 2500:X!=X:PRINT TAB(5)"Series Capacitive Reactance i
s ";X!;"ohms (";C!;"pFd)"   'Same procedure as for shunt element (line 2020)
2040 IF X>0 THEN GOSUB 2510:X!=X:PRINT TAB(5)"Series Inductive Reactance is ";X!
;"ohms (";L!;CHR$(230);"H)"   'Same procedure as for shunt element (line 2010)
2050 IF X=0 THEN PRINT TAB(5)"No Series Reactance Required"   'Special case
2060 IF RO=RA THEN PRINT TAB(10)"(Transmitter sees ";RO;"ohms resistive.)"
  'Special case
2070 RETURN
2500 C=-1E+09/(2*3.141593*F*X):C!=C:RETURN   'Calculate capacitance and convert
  to single precision
2510 L=X*1000/(2*3.141593*F):L!=L:RETURN   'Calculate inductance and convert
  to single precision
3000 Z=SQR(((RA^2*XSH^2)+(XSH^2*(XA+XS)^2))/(RA^2+(XA+XS+XSH)^2))   'Calculate
  magnitude of impedance at network input (second configuration)
3010 A=ATN(-RA/(XA+XS))-ATN((XA+XS+XSH)/RA):XS=0:GOSUB 3080:RETURN   'Calculate
  phase angle of impedance at network input. Continue at 3080
3020 Z=SQR(((XA^2*XSH^2)+(RA^2*XSH^2))/(RA^2+(XA+XSH)^2))   'Calculate magnitude
   of impedance beyond series element (first configuration)
3030 IF XA=0 THEN R1=-3.141593/2:GOTO 3050   'Avoid division by zero in next step
3040 R1=ATN(-RA/XA)   'Get phase angle of numerator, first configuration
3050 R2=ATN((XA+XSH)/RA)   'Get phase angle of denominator, first configuration
3060 A=R1-R2   'Phase angle of input impedance, first configuration
3070 IF COS(A)<0 THEN R1=3.141593+R1:GOTO 3060   'Check for ambiguity in arctan
  calculations and correct if necessary
3080 ZRE=Z*COS(A):IF ZRE>RO*.999 AND ZRE<RO*1.001 THEN ZRE!=RO ELSE ZRE!=ZRE
  'Calculate resistive component and ignore inaccuracies under 0.1 percent
3090 ZIM=(Z*SIN(A))+XS:IF ABS(ZIM)<.001*RO THEN ZIM=0:PRINT TAB(10)"(Transmitter
 sees";ZRE!;"ohms resistive.)":RETURN   'Calculate reactive component, add series
  element. If total is under 0.1 percent of RO round to zero and print results.
3100 ZIM!=ZIM:PRINT TAB(10)"(Transmitter sees ";ZRE!;"+j";ZIM!;"ohms.)"   'If
  reactive component is significant, print check result in complex notation
3110 RETURN
4000 IF ERR=5 OR ERR=11 THEN PRINT TAB(5)"No First-Case Solution":PRINT:RESUME 1
110   'Error handling for first case, first configuration
4010 IF ERR=5 OR ERR=11 THEN PRINT TAB(5)"No Second-Case Solution":PRINT:RESUME
1140   'Same for second case, first configuration
4020 IF ERR=5 OR ERR=11 THEN PRINT TAB(5)"No Solution for This Configuration":RE
SUME 4500   'Same for second configuration
4500 LOCATE 23,1,0:PRINT"CALCULATE ANOTHER (Y OR N)?":K$=INKEY$:IF K$=""THEN 450
0
4510 IF K$="Y"OR K$="y"THEN 1000 ELSE END
```

Program in GW-BASIC for calculation of L-match configurations. For maximum accuracy in the checking routine (lines 3000 through 3100) the program should be run under BASIC loaded with the double-precision transcendental math package (load BASIC/D instead of normal BASIC).

FIGURE 4



SWR curves and matching network for 160-meter dipole.

Measuring the input impedance of the line at 1835 kHz shows 95 ohms resistance (R_a) and a small amount (estimated as 5 ohms) of inductive reactance (X_a). The computer calculation shows that a network with 4.5 μH of series inductance and 914 pF of shunt capacitance would provide a match to 50 ohms.

The shunt capacitor in my device is a 700-pF mica transmitting capacitor from a war surplus TU-10B tuning unit. It has a 200-pF high-voltage disk ceramic in parallel to give 900 pF. This is close to the calculated 914 pF — closer, in fact, than the probable accuracy of the measurements.

The coil in this unit is wound of no. 12 soft-drawn bare copper wire using a piece of 1-inch PVC pipe as a mandrel. Wire this large isn't necessary, but I had it on hand. It makes a coil that's virtually self-supporting, and it's easy to solder a tap anywhere on the bare wire.

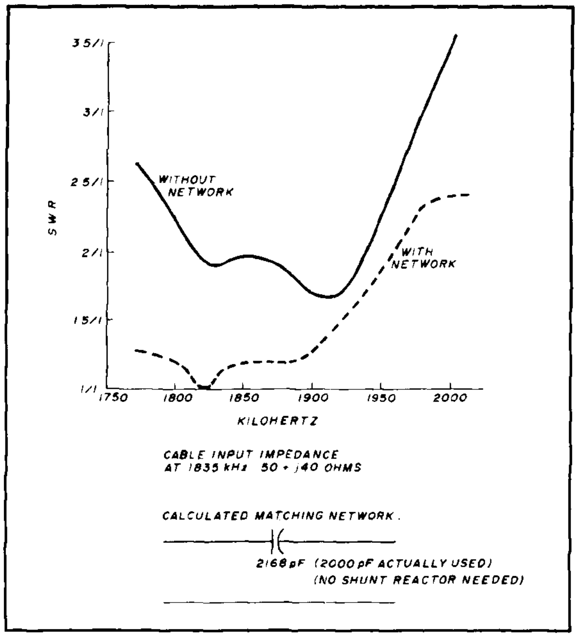
The SWR curve taken with the final network in place shows a perfect 1:1 at the design frequency of 1835 kHz, and a major improvement in the SWR seen by the transmitter over the entire range from 1800 to 1900 kHz. This network is permanently connected in the line and not equipped with a by-pass switch, as are some of the others I'll describe.

Quarter-wave 160-meter sloper

Figure 5 shows a network consisting of a single capacitor, which I use to correct the SWR of the line to a quarter-wave 160-meter sloper.

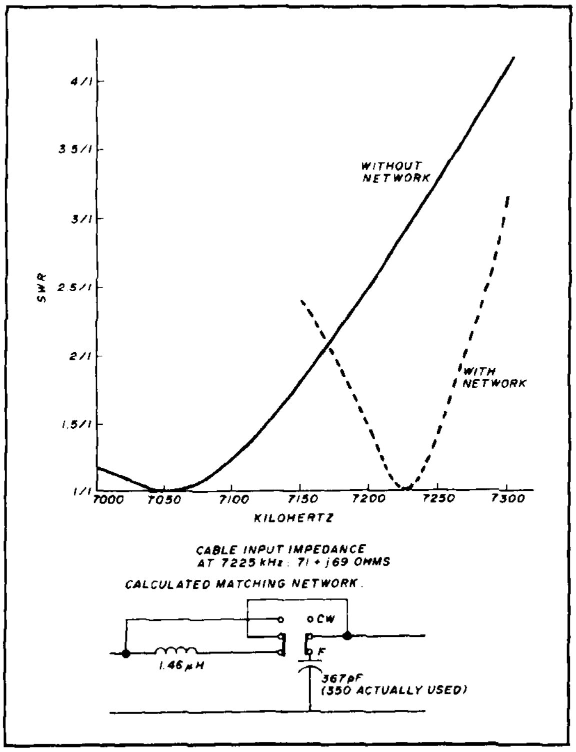
At first, there was no sign of resonance or a match to the cable anywhere in the band with the sloper alone in its original installation on a 70-foot tower. The SWR was extremely high — a disappointing but common situation

FIGURE 5



SWR curves and L-network for 160-meter sloper.

FIGURE 6



SWR curves and L-network for 40-meter Yagi.

with quarter-wave slopers. I installed a quarter-wave counterpoise, grounded to the top of the tower, at a right angle to the sloper. By carefully trimming the lengths of both the antenna and the counterpoise, I brought the SWR to a minimum of 1.9:1 at 1830 kHz. Minimum SWR was still rather poor — 1.6:1 at 1910 kHz. Measurement of the input impedance of the cable at 1835 kHz showed very nearly 50 ohms of resistance and about 40 ohms of inductive reactance. The computer calculation showed that 2168 pF in series with the line would provide a match, with no shunt reactor. Eureka! I mounted a 0.002-μF 2500-volt mica capacitor from the junkbox in a minibox. This "network" is shown in **fig. 5**, with the resulting SWR curve — a perfect 1:1 at 1820 kHz, and very low SWR from 1800 to 1900 kHz. For obvious reasons, this network is permanently installed in the line and there's no by-pass switch.

40-meter Yagi

Figure 6 shows the SWR curve at the input end of the cable to my 3-element 40-meter Yagi, which is tuned and matched for the CW portion of the band. The SWR is 1:1 at 7045 kHz, but rises radically in the phone portion of the band. At 7225 kHz, the center of the phone band, the SWR is 2.9:1. The measured input impedance of the cable at this frequency is 71 ohms of resistance and 69 ohms of inductive reactance.

For this situation, the formulas give 1.46 μH of series inductance with 367 pF of shunt capacitance on the antenna side for a match to 50 ohms at 7225 kHz.

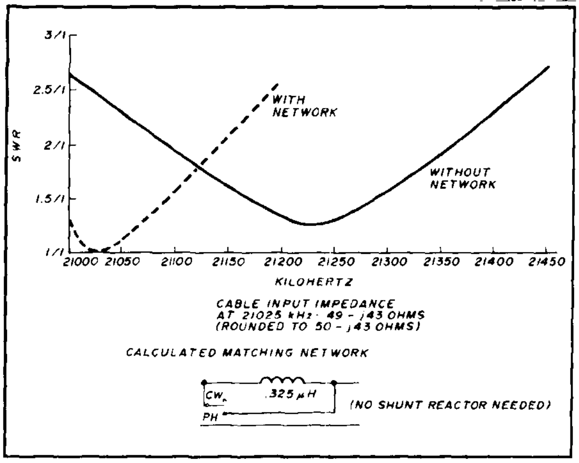
The capacitors in the resulting matching unit are two transmitting ceramic capacitors (one 200 pF and one 100 pF) and a 50-pF high-voltage disk ceramic capacitor, all connected in parallel to give 350 pF. The matching unit has a slide switch so I can by-pass it for CW operation. The SWR seen by the transmitter is 1:1 at 7225 kHz with the network in operation, but for reasons mentioned previously it rises above 2:1 beyond 7270 kHz.

15-meter Yagi

My 4-element 15-meter Yagi was originally cut and matched for a compromise between the phone and CW portions of the band. **Figure 7** shows that the minimum SWR on the cable is a fairly acceptable 1.28:1 at 21,220 kHz, but rises to 2.7:1 at the high (phone) end of the band and 2.6:1 at the low (CW) end. The high SWR at the band ends presented no compensation problem for the loading capacitor used on my amplifier for this band, and I seldom operate above 21,350 kHz. Touching up the tuning on the air after first tuning into a dummy load for CW not only took extra time, but bothered my conscience as well.

Measurement of the input impedance of the cable at 21,025 kHz showed a resistive component just under

FIGURE 7



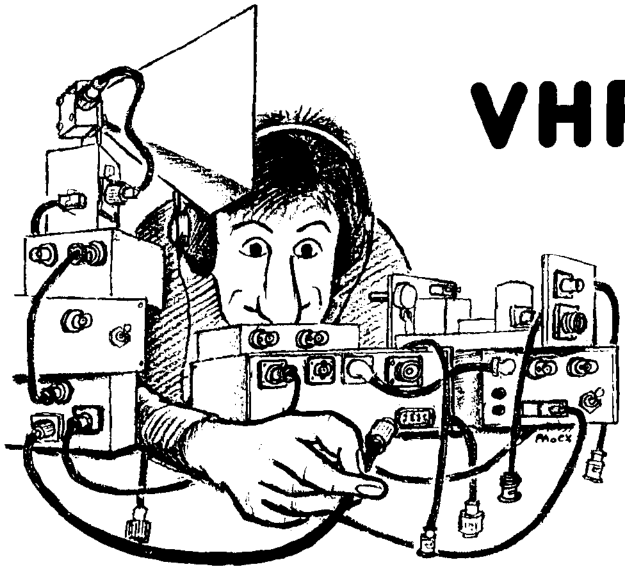
SWR Curves and L-network for 15-meter Yagi.

50 ohms (close to 49 ohms) and a capacitive reactance of about 43 ohms. One of the solutions given by calculations for the first configuration for this impedance was a series inductance of 0.324 μH (42.9 ohms) and a shunt inductance of 32.2 μH (a very high 4250 ohms of inductive reactance). It was apparent that I needed the shunt reactance just to raise the resistive component of the load from 49 to 50 ohms, a mere 2-percent change. Another calculation showed that with the resistive component of the load rounded to 50 ohms, a 0.325-μH series inductor would provide a match with the shunt element omitted. This simpler network was adequate, as indicated by the resulting SWR curve. The SWR is a perfect 1:1 at 21,025 kHz and is quite low over all of the first 100 kHz of the band.

This must be one of the smallest 1-kW antenna tuners in existence! It consists of only an 8-turn 1/2-inch diameter coil and contains a 2-position rotary selector switch to by-pass the coil for phone operation.

Now when I QSY to 15-meter CW, I tune the amplifier into the dummy load, switch to the antenna with the network in, and proceed without causing any tuning QRM. It's a much better feeling!

Article D **HAM RADIO**



VHF/UHF WORLD

Joe Reisert, W1JR

DX records on 50 MHz and above: part 2

Last month's column[1] discussed how VHF/UHF and above DX records are made, and their relative importance to Amateur Radio and the state of the art (SOA). I also reviewed some of the most recent record-breaking contacts using ionospheric and tropospheric propagation.

This month I'll continue along on the same subject with emphasis on EME and tropospheric propagation records. The updated DX record tables will appear at the end of the column.

EME

There are still lots of challenges to using EME communications. Although the EME DX records on 144, 432, and 1296 MHz extend virtually halfway around the world, other bands are wide open for increased DX records.

As you'll see shortly, some of these opportunities have not gone unnoticed. Records and technology march on, but don't be discouraged. If you look at the EME records you'll find some interesting opportunities for getting into the record tables.

50 MHz

For over a decade, 6-meter EME was in the doldrums. However, as I've reported in "VHF/UHF World" lately, that interest has not only been rekindled — it has proliferated — and several new stations have joined the fun.

Stations outside North America are now active. The most recent station to participate is Graham Jonas, ZL2BGJ, near Wellington, New Zealand (RF70DX). He's built a huge multiwire rhombic antenna with an estimated gain of 25 dB. The antenna's radiation center intercepts the moon whenever it passes through about 16.5 degrees north declination and 130 degrees Greenwich Hour Angle. This rhombic can be steered a few degrees if necessary.

ZL2BGJ's first big 6-meter EME test was on September 7, 1988 between 1800 and 1815 UTC when he worked Jim Treybig, W6JKV, Los Altos Hills, California (CM87WI) for a new world record of 6704 miles (10,787 km). Graham was running about 650 watts. Jim was running 1500 watts to a quad of 10-element M^2 Yagis, each on a 52-foot boom.

The following day (September 8, 1988), Graham ran a schedule with Ray Rector, WA4NJP, Gillsville, Georgia (EM84DG) between 1900 and 1915 UTC and they completed a contact extending the worldwide DX record to 8258 miles (13,288 km). Ray was running 1500 watts to a quad of 8-element W1JR-type Yagis, each on a 34-foot boom.[2] I propped a similar 8-element Yagi up on a small tower and was able to hear portions of both sides of this contact.

10 GHz

For some time, a 3-cm EME contact has been considered one of the last big EME "plums." As I mentioned in a recent column, several stations have been diligently working towards that goal.[3] Several one-way contacts have been reported, but the two-way contact eluded most aspirants.

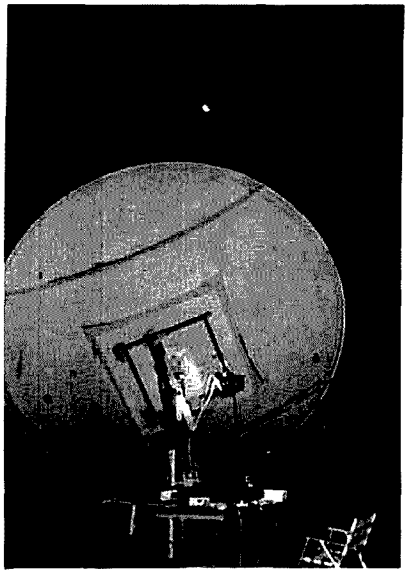
Well, it finally happened, and by a different group than was reported in **reference** 3. Several schedules had been run during August, but bad weather ruined the final contact because water vapor is an attenuator at these frequencies.[4]

Finally on August 27, 1988 at 0935 UTC an EME contact was completed on approximately 10.368 GHz between Greg Raven, KF5N, and Kent Britain, WA5VJB, operating under the callsign WA5VJB from Grand Prairie, Texas (EM12LQ) and Dave Chase, KY7B and Jim Vogler, WA7CJO operating under the callsign WA7CJO from Cave Creek, Arizona (DM33XL) over a terrestrial distance of about 868 miles (1937 km).

Signals were Q5 but weak and broad, almost auroral in quality, and spread out over perhaps 1 kHz (probably due to libration fading). Because most of the schedules were conducted with the moon south of the path, doppler was observed up to ± 20 kHz. Both stations aimed their antennas by peaking on "moon noise," which ran close to 1 dB.

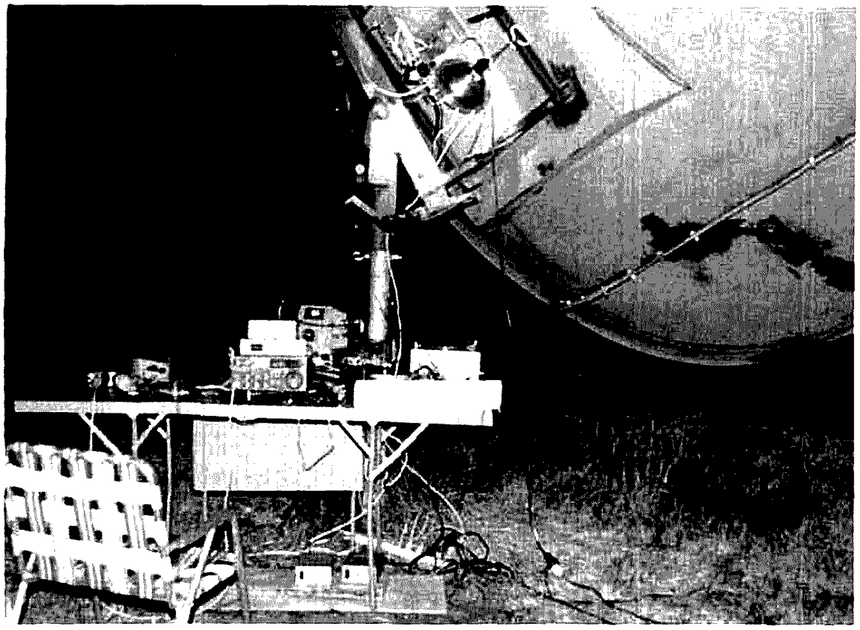
The WA5VJB station used a 12-foot dish with a linear polarized waveguide splasher feed that can be rotated to align polarity on the incoming signal. Kent estimated the dish gain to be 49 dBi with a beam width of 0.56 degrees (this gain figure may be optimistic). The transmitter delivered 50 watts of output from a surplus TWT. The receiver was a modified SSB Elec-

PHOTO A



The 12-foot dish at station WA5VJB used for the first ever two-way Amateur contact on 10-GHz EME.

PHOTO B



Gear set up in the backyard just below the dish.

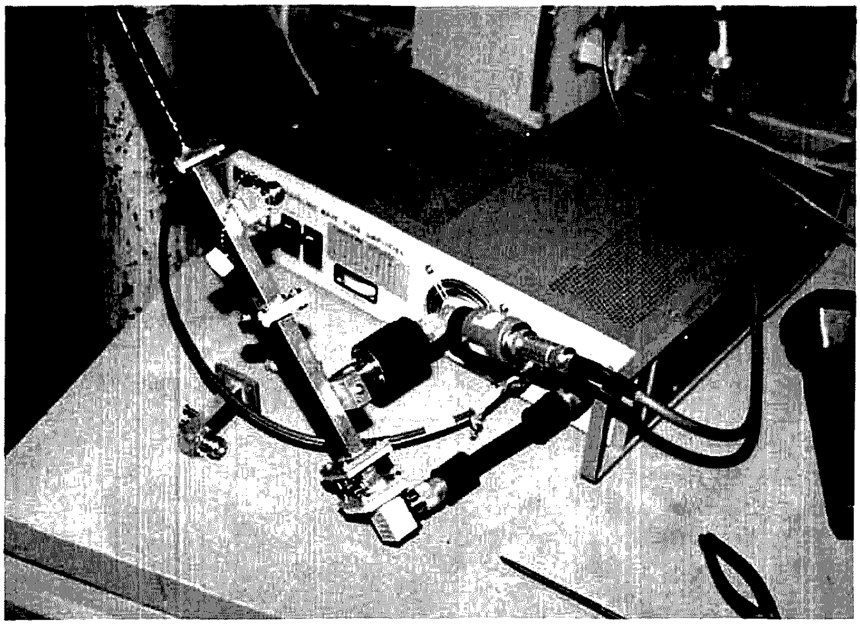
tronics transverter preceded by five stages of low-noise Avantek AT-13135 GaAsFETs that downconvert to 144 MHz. The overall system noise figure is approximately 2.1 dB. Some of the station equipment is shown in **photos A**, B, and **C**.

The WA7CJO station used a 16-foot dish with an estimated gain of 51 dBi and a beam width of 0.42 degrees with a scalar feed. The transmitter ran 85 watts of output power from a surplus TWT. The receiver was completely homebrew, with an image rejection mixer feeding a 28-MHz IF. The preamplifier was similar to WA5VJB's with an overall system noise figure of 1.5 dB.

A few weeks after the first-ever 3-cm Amateur EME contact was completed, I received a telephone call from Rick Fogle, WA5TNY. He reported that Lucky Whitaker, W7CNK/5, Oklahoma City, Oklahoma (EM15FI) had also completed a two-way contact on 10.368-GHz EME with WA7CJO on September 25, 1988.

Lucky runs 32 watts from a solid-state amplifier to a 16-foot fiber glass TVRO dish.[3] Lucky and Rick now feel

PHOTO C



The TWT power amplifier connected to the waveguide feedline.

that, due to surface inaccuracies, the performance of his dish probably puts him in the class of an equivalent 11-foot dish with good surface accuracy.

On September 26th Rick completed not one, but two, contacts with WA7CJO. Rick is located in Grapevine, Texas (EM12KV) and runs 14 watts from a solid-state amplifier. Rick recently upgraded to a 10-foot "spun

aluminum" dish. Apparently the extra surface accuracy helped. His sun noise increased from 9.5 to 13.2 dB over that which he received from the older 10-foot TVRO-type dish he used to set the first-ever 3.4 and 5.6-GHz EME contacts.

The EME contacts made by Rick and Lucky were both just short of the distance of the WA5VJB/WA7CJO contact. There are lots of solid-state transverters out there on 10.368 GHz. Likewise, 10-foot spun aluminum dishes are available. It seems the only things holding up contacts are the lack of participants and suitable power amplifiers. When the amplifiers become available, there may be many more 3-cm EME contacts.

300 GHz and up

As most SHFers know, all frequencies above 300 GHz are open for Amateur Radio. "And then there was light" is a better explanation of many of these frequencies, because some of this spectrum covers the "visible light" range.

When Amateurs first obtained this frequency spectrum, some were quick to respond. They submitted contest contacts when the only communication involved was two people sending code to each other with flashlights. But these early contacts may not have been possible over the minimum 1 mile unless telescopes were used, and that really wasn't what was intended for contest contacts!

As a result, the ARRL modified the contest rules to require that all contest contacts in this frequency spectrum be made between licensed Amateurs using coherent radiation on transmission (eg., laser) and employing at least one stage of electronic detection on receive. Furthermore, in July 1988 the ARRL announced that effective September 1, 1988, there would be a separate VUCC Award for anyone submitting proof of contacts with five grid squares fitting the above mentioned definition.

"VHF/UHF World" has recognized such contacts since the first North American DX Record table was published in July 1985.[5] Until recently, only two contacts had been reported. The record was 15 miles on 474 THz. But I recently received a contact report at 678 THz! The contact was made between Dave Chase, KY7B/7, operating from Mt. Lemmon, Arizona (DM42OK) and Terry Wilkinson, WA7LYI/7, on Mt. Graham, Arizona (DM52BQ) at a distance of 56.7 miles (91.25 km).

All the equipment used for this contact was homebrew. It included surplus lasers, a micrometer positioning system, and a "muffin fan" modulator! The signals were MCW at a power level of 24-48 milliwatts.

The receiver used a Fresnel lens, photo multiplier tube, and an audio amplifier. **Photos D, E,** and **F** show parts of the system. I'm sure we'll be hearing more about their equipment shortly.

Interestingly enough, the biggest problem Dave and Terry encountered in making this contact was "finding" each other. It took three hours. At 56.7 miles, the beam width of the transmitted signal was only 50 feet! They already have plans to break their own record.

For now, I'll show both long DX contacts made above 300 GHz since they were made in different portions of the visible spectrum. Should the records in this spectrum be subdivided? Perhaps one of you can come up with a more equitable way to list these records. I'd appreciate any suggestions.

Last-minute update

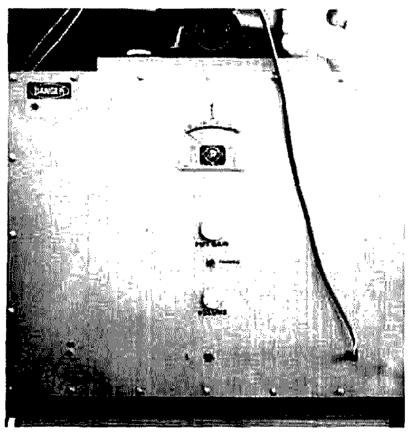
It happened again! Another new record came in just as I was finishing this column. The record is on 33 cm (903 MHz).

On September 28, 1988, there was excellent tropo propagation between New Jersey and Georgia on 2 meters and 70 cm. At 0413 UTC, Roger Amidon, K2SMN, near Princeton, New Jersey (FN20EJ) completed a CW contact on 903.1 MHz with Steve Adams, WS4F, Cornelia, Georgia

PHOTO D

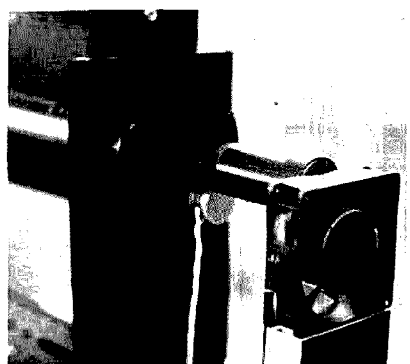
An overall view of the receiver (the engine hoist is not part of the receiver!) used to set the new 678-THz DX record.

PHOTO E



A closeup of the receiver.

PHOTO F



The 1-kHz modulator, a muffin fan!

TABLE 1

North American VHF and above claimed DX records. (Revised 88-10-27)

Frequency	Record Holders	Date	Mode	DX Miles (km)
50 MHz	See note 4.			
EME	WA4NJP(EM84DG)-ZL2BGJ(RF70DX)	88-09-08	CW	8258 (13288)
144 MHz				
Aurora	KA1ZE(FN31TU)-WA0TKJ/WB0DRL(EM18CT)	86-02-08	CW	1347 (2167)
EME	VE1UT(FN63XV)-VK5MC(QF02EJ)	84-04-07	CW	10,985 (17676)
FAI	W5HUQ/4(EM90GC)-W5UN(DM82WA)	83-07-25	CW	1228 (1976)
MS	K5UR(EM35WA)-KP4EKG(FK68VG)	85-12-13	SSB	1960 (3153)
Spor. E	WA4CQG(EM72FO)-W7YOZ(CN87VR)	88-06-06	SSB	2172 (3495)
TE	KP4EOR(FK78AJ)-LU5DJZ(GF11LU)	78-02-12	SSB	3933 (6328)
Tropo OL	K1RJH(FN31XH)-K5WXZ(EM12QW)	68-10-08	CW	1468 (2362)
Tropo OW	KH6GRU(BL01XH)-WA6JRA(DM13BT)	73 07 29	CW	2586 (4161)
220 MHz				
Aurora	W3IY/4(FM19HA)-WB5LUA(EM13QC)	82-07-14	CW	1145 (1842)
EME	K1WHS(FM43MK)-KH6BFZ(BL11CJ)	83-11-17	CW	5058 (8139)
MS	W1JR(FN42HN)-K0ALL(EN16OU)	88-08-13	SSB	1274 (2057)
Spor. E	K5UGM(EM12MS)-W5HUQ/4(EM90GC)	87-06-14	CW/SSB	932 (1499)
TE	KP4EOR(FK78AJ)-LU7DJZ(GF05RJ)	83-03-09	CW/SSB	3670 (5906)
Tropo OL	K1WHS(FM43MK)-K5UR(EM35WA)	88-09-09	CW	1267 (2039)
Tropo OW	KH6UK(BL11AQ)-W6NLZ(DM03TS)	59-06-22	CW	2539 (4086)
432 MHz				
Aurora	W3IP(FM19PD)-WB5LUA(EM13QC)	86-02-08	CW	1182 (1901)
EME	K2UYH(FN20QG)-VK6ZT(QF78VB)	83-01-29	CW	11567 (18612)
MS	W2AZL(FN20VI)-W0LER(EN35IE)	72-08-12	CW	1021 (1642)
Tropo OL	WB3CZG(FN21AX)-WA5VJB(EM12LQ)	86-11-29	SSB	1318 (2121)
Tropo OW	KD6R(DM13NI)-KH61AA/P(BK29GO)	80-07-28	CW	2550 (4103)
903 MHz				
EME	K5JL(EM15DQ)-WB5LUA(EM13QC)	88-02-07	CW	187 (301)
Tropo OL	K2SMN(FN20EJ)-WS4F(EM84FM)	88-09-28	CW	628 (1011)
1296 MHz				
EME	K2UYH(FN20QG)-VK5MC(QF02EJ)	81-12-06	CW	10562 (16995)
Tropo OL	WB3CZG(FN21AX)-KD5RO(EM13PA)	86-11-29	CW	1287 (2070)
Tropo OW	KH6HME(BK29GO)-WB6NMT/6(DM12KU)	86-08-13	SSB	2528 (4068)
2304 MHz				
EME	W3IWI/8(FM08CK)-ZL2AQE(RE78JS)	87-10-18	CW	8658 (13931)
Tropo OL	KD5RO(EM13PA)-W8YIO(EN82BE)	86-11-29	CW	940 (1513)
3456 MHz				
EME	W7CNK/5(EM15FI)-K0KE/0(DM79NO)	87-04-12	CW	498 (802)
Tropo OL	WB5AFY(EM04ID)-KX0O/0(DM78KU)	88-08-07	CW	455.5 (733)
5760 MHz				
EME	WA5TNY(EM12KV)-W7CNK/5(EM15FI)	87-04-24	CW	174 (279)
Tropo OL	N5JJZ/5(EM26CB)-WA5ICW/5(DM86LR)	88-07-10	SSB	404 (650)
10.368 GHz				
EME	WA5VJB(EM12LQ)-WA7CJO(DM33XL)	88-08-27	CW	868 (1397)
Tropo OL	WB7ABP/P(CN81QB)-WB0HLC/6(DM04MS)	88-08-06	CW/SSB	479 (770)
Tropo OW	NN6W/6(CM94XM)-XE2GFH(DL27VL)	88-09-11	MCW	595 (958)
24.192 GHz				
LOS	WA3RMX/7(CN93IQ)-WB7UNU/7(CN95DH)	86-08-23	SSB	116 (186)
47.040 GHz				
LOS	WA3RMX/7(CN82VW)-K7AUO/7(CN82PB)	88-08-06	CW/SSB	65.3 (105)
76-149 GHz	None reported.			
300 GHz and above	See note 5.			
474 THz				
LOS	K6MEP/6(DM04IO)-WA6EJO/6(DM04KT)	79-06-09	Laser	15 (24)
678 THz				
LOS	KY7B/7(DM42OK)-WA7LYI/7(DM52BQ)	88-06-12	Laser	56.7 (91.2)

Note 1. The records are listed alphabetically by mode. Tropo OL is over land. Tropo OW is over water (at least 75 percent of the path).
Note 2. The information within the brackets () following the callsign is the grid square locator.
Note 3. Distances have been calculated assuming a spherical earth model using the actual latitude and longitude rather than using the less accurate grid square centers model.
Note 4. Six-meter records, excepting EME, were left off as the primary propagation mode is often hard to distinquish. Long-path QSOs exceeding approximately 12430 miles (20000 km) have been reported during solar cycles 19, 21, and 22.
Note 5. There have been very few reports of contacts in the wide open frequency allocation above 300 GHz. Therefore, at least for the time being, we will list those records that show considerable distance at widely different frequencies.

TABLE 2

Worldwide claimed VHF/UHF/SHF terrestrial DX records. (Revised 88-10-27)

Frequency	Record Holders	Date	Mode	Miles (km)
50 MHz	Note 3			
70 MHz	GW4ASR/P(IO82JG)-5B4CY (KM64MR)	81-06-07	Es	2153 (3465)
144 MHz	I4EAT(JN54VG)-ZS3B(JG73OI)	79-03-30	TE	4884 (7860)
220 MHz	KP4EOR(FK68XM)-LU7DJZ(GF05RJ)	83-03-09	TE	3670 (5906)
432 MHz	KD6R(DM13NI)-KH6IAA/P(BK29GO)	80-07-28	Duct	2550 (4103)
903 MHz	K2SMN(FN20EJ)-WS4F(EM84FM)	88-09-28	Tropo	628 (1011)
1296 MHz	KH6HME(BK29GO)-WB6NMT(DM12KU)	86-08-13	Duct	2528 (4068)
2304 MHz	VK5QR(PF95HD)-VK6WG/P(OF85WA)	78-02-17	Duct	1170 (1883)
3456 MHz	VK5QR(PF95HD)-VK6WG(OF85WA)	86-01-25	Duct	1171 (1885)
5760 MHz	G3ZEZ(JO01MS)-SM6HYG(JO58RG)	83-07-12	Duct	610 (981)
10.3 GHz	I0SNY/EA9(IM75IV)-I0YLI/IE9(JM68NR)	83-07-08	Duct	1032 (1660)
24 GHz	I0SNY/IC8(JN60WR)-I8YZO/8(JM78WE)	84-08-11	LOS	206 (331)
47 GHz	WA3RMX/7(CN82VW)-K7AUO/7(CN82PB)	88-08-06	LOS	65.3 (105)
75 GHz	HB9AGE/P(JN37RD)-HB9MIN/P(JN37RD)	85-12-30	LOS	0.3 (0.5)
474 THz	K6MEP(DM04IO)-WA6EJO(DM04KT)	79-06-09	LOS	15 (24)
678 THz	KY7B/7(DM42OK)-WA7LYI/7(DM52BQ)	88-06-12	LOS	56.7 (91.2)

Notes:
1. The information within the brackets () after the callsign is the grid square locator.
2. Distances have been calculated assuming a spherical earth model. The actual latitude and longitude are used rather than the less accurate grid square centers model.
3. Six meters has been left blank on this listing because long-path QSOs (those exceeding approximately 12430 miles or 20000 km) have been reported during solar cycles 19, 21, and 22.

(EM84EM), over a distance of 628 miles (1011 km). This extends the previous record by about 5 miles and shows why it's good to know exact station coordinates.

Roger was running 80 watts to a quad array of 23-element Tonna Yagis. Steve was running 130 watts to a single 33-element loop Yagi. Both stations had system noise figures below 1.0 dB. Signals were several dB out of the noise.

Latest DX record tables

Here are the latest record tables; they've all been updated. Note changes in grid squares since the last time these tables were published. Many locations have been more accurately determined.

I made a few typographical errors in the previous tables. I hope they didn't cause any grief. If you find mistakes or have questions on the data shown in any of the tables, please let me know. After all, this is a process of evolution and you can't challenge a record that has incorrect data.

Table 1 shows the latest North American DX records, **table 2** the latest worldwide DX records, and **table 3** the latest EME records — including the first-ever 3-cm contact.

Region 1 DX Records

Up until now, the tables published in "VHF/UHF World" have only recognized North America and worldwide DX records. There are other long distance contacts that, while not records on these tables, are still rather interesting and impressive.

Some of these contacts include the records made in Region 1, which includes Europe, Africa, and the Soviet Republics. These records reflect the SOA in other parts of the world and I think they're important. Also, several VHF and above devotees have been questioning me on what our peers outside North America are doing.

For several years Region 1 DX records have been carefully

TABLE 3

Worldwide claimed VHF/UHF/SHF EME DX records. (Revised 88-10-27)

Frequency	Record Holders	Date	Mode	Miles (km)
50 MHz	WA4NJP(EM84DG)-ZL2BGJ(RF70DX)	88-09-08	CW	8258 (13288)
144 MHz	K6MYC/KH6(BK29AO) ZS6ALE(KG43RC)	83-02-18	CW	12091 (19455)
220 MHz	K1WHS(FN43MK)-KH6BFZ(BL11CJ)	83-11-17	CW	5058 (8139)
432 MHz	F9FT(JO29AG)-ZL3AAD(RE66GR)	80-04-18	CW	11679 (18793)
902 MHz	K5JL(EM15DQ)-WB5LUA(EM13QC)	88-02-07	CW	187 (301)
1296 MHz	PA0SSB(JO11WI)-ZL3AAD(RE66GR)	83-06-13	CW	11595 (18657)
2304 MHz	W3IWI/8(FM08CK)-ZL2AQE(RE78JS)	87-10-18	CW	8658 (13931)
3456 MHz	W7CNK/5(EM15FI)-K0KE(DM79NO)	87-04-06	CW	498 (802)
5760 MHz	WA5TNY(EM12KV)-W7CNK/5(EM15FI)	87-04-24	CW	174 (279)
10368 MHz	WA5VJB(EM12LQ)-WA7CJO(DM33XL)	88-08-27	CW	868 (1397)
24000 MHz and above	None reported.			

Notes:
1. The information within the brackets () following the callsigns is the grid square locator.
2. The distances shown have been calculated assuming a spherical earth model. The actual latitudes and longitude are used rather than the less accurate grid square centers model.

documented by Folke Rosvall, SM5AGM, who updates them annually. Most, but not all, of the DX records shown in **table 4** are from the list published by Folke. However, I reserve the right to update them myself. I plan to include some impressive tropo and aurora claims that don't appear in Folke's table, or are very recent. Some Region 1 DX records, like FAI, aren't included or available, but I hope they will be in the near future.

I must make one final point about **table 4.** Folke determined most of the distances on this table using the new "ellipsoidal" earth model for distance determination. In some cases, interpretation may be necessary when comparing these records with those shown in **tables 1, 2,** and **3**. What are your impressions of **table 4**? Do you find it valuable?

Summary

January and February's columns are dedicated to those who have tried as well as those who have succeeded in setting new VHF and above DX records — an important aspect of Amateur Radio.

In a sense these columns have been like an anatomy of how the records are achieved and how they improve the SOA. I hope that this background material and the challenges I've described will encourage you to try to improve the SOA and/or make an attempt at one of the many records available to those who operate above 50 MHz.

In the meantime, please keep me informed of your progress on new record attempts or challenges. Remember to write to me for a "VHF/UHF/SHF Propagation Record Verification Form," or fill out a copy of **table 4** on page 47 of the June 1988 column.[3]

Acknowledgments

I'd like to thank all who submitted DX record information — especially for January and February's columns. In particular I'd like to thank (and I hope I don't miss anyone): K1WHS, WA3RMX, WA4NJP, KB4WM, WA5ICW, K5UR, WA5VJB, N6XQ, KY7B, W7YOZ, KXØO, and WBØHLO.

Notes

In last September's column[6] I listed the addresses of several VHF publications. I've recently been informed that two have changed as follows:

2-Meter EME Bulletin, c/o R.E. Turner, 14826 Daisy Lane, Tampa, Florida 33613.

MidWest VHF/UHF Society, c/o Steve Whitefield, WA3OJX, 400 S. Main Street, Springboro, Ohio 45066. This monthly publication is available for $6.00 per year.

Important VHF/UHF Events

February 6	*New Moon*
February 7	*EME perigee*
February 20	*Total lunar eclipse*
March 7	*New moon with partial solar eclipse*
March 8	*EME perigee*
March 21	±2 weeks. Optimum time for TE propagation

TABLE 4

IARU Region 1 VHF and above claimed DX records. (Revised 88-10-27)

Frequency	Record Holders	Date	Mode	DX miles (km)
50 MHz				
F2	EL2AV(IJ46)-H44PT(RI00OA)	82-04-04	SSB	11764 (18932)
70 MHz				
Aurora	G3SHK(IO90DX)-GM3WOJ/P(IO89KB)	82-08-11	CW	562 (904)
MS	GJ3YHU(IN89XI)-GM3WOJ/P(IO89KB)	82-08-12	?	673 (1083)
Spor. E	GW4ASR/P(IO82JG)-5B4CY(KM64MR)	81-06-07	?	2153 (3465)
Tropo	G4FRE/P(IO70PP)-GM4ZUK/A(IO87WB)	86-09-21	SSB	456 (734)
144 MHz				
Aurora	G4VBG(IO94FW)-UA32FI(KO76WT)	86-02-07	CW	1373 (2209)
EME	K6MYC/KH6(BK29AO)-ZS6ALE(KG46RC)	84-02-18	CW	12091 (19455)
MS	GW4CQT(IO81LP)-UW6MA(KN97VE)	77-08-12	CW	1927 (3101)
Spor. E	EA8XS(IL28GA)-HG0HO(KN07RU)	83-07-16	SSB	2402 (3865)
TE	I4EAT(JN54VG)-ZS3B(JG73OI)	79-03-30	CW	4884 (7860)
Tropo	EA8BEX(IL27GX)-GI4KIS(IO64VR)	88-07-15	CW/SSB	1904 (3064)
432 MHz				
Aurora	PA0RDY(JO22KJ)-RA3LE(KO64AR)	86-02-08	CW	1123 (1807)
EME	F9FT(JN29AG)-ZL3AAD(RE66GR)	80-04-18	CW	11749 (18907)
MS	EI2VAH(IO43XW)-SK6AB(JO57XQ)	80-08-12	CW	891 (1434)
Tropo	EA8XS(IL28GA)-GW8VHI(IO81CM)	84-07-05	SSB	1731 (2786)
1296 MHz				
EME	PA0SSB(JO11WI)-ZL3AAD(RE66GR)	83-06-13	CW/SSB	11665 (18772)
Tropo	EA8XS(IL26GA)-G6LEU(IO70ME)	85-06-29	SSB	1626 (2617)
2304 MHz				
EME	PA0SSB(JO11WI)-W6YFK(CM87WJ)	81-04-05	CW/SSB	5506 (8860)
Tropo	EA7BVD/P(IM78JD)-EA8XS/P(IL27GW)	84-07-08	SSB	920 (1481)
3456 MHz				
Tropo	G3LQR(JO02QF)-SM6HYG(JO58RG)	83-07-11	CW	576 (927)
5760 MHz				
Tropo	G3ZEZ(JO01MS)-SM6HYG(JO58RG)	83-07-12	CW/SSB	610 (981)
10.368 GHz				
Tropo	I0SNY/EA9(IM75IV)-I0YLI/IE9(JM68NR)	83-07-08	FM	1032 (1660)
24 GHz				
Tropo	I0SNY/IC8(JN60WR)-I8YZO/8(JM78WE)	84-08-11	FM	206 (331)
47 GHz				
Tropo	HB9AGE/P(JN36FS)-HB9MIN/P(JN36SX)	87-06-06	?	53 (86)
75 GHz				
LOS	HB9AGE/P(JN37RD)-HB9MIN/P(JN37RD)	87-06-06	FM	0.3 (0.5)

Notes:
1. The records are listed alphabetically by mode.
2. The information within the brackets () following the callsign is the grid square locator.
3. The distances are calculated using an ellipsoidal earth model.

References

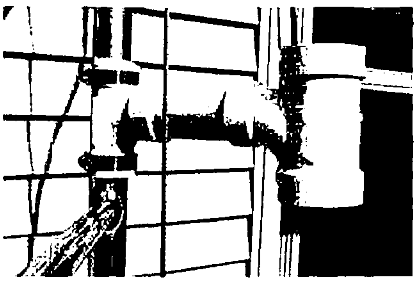
1. Joe Reisert, W1JR, "VHF/UHF World-DX Records on 50 MHz and Above-Part 1," *Ham Radio*, January 1989, page 48.
2. Joe Reisert, W1JR, "VHF/UHF World-Optimized 2- and 6-Meter Yagis," *Ham Radio*, May 1987, page 92.
3. Joe Reisert, W1JR, "VHF/UHF World-Propagation Update-Part 2," *Ham Radio*, June 1988, page 39.
4. Joe Reisert, W1JR, "VHF/UHF World-Microwave and Millimeter-wave Propagation, Part 2," *Ham Radio*, August 1986, page 69.
5. Joe Reisert, W1JR, "VHF/UHF World-Propagation Update," *Ham Radio*, July 1985, page 86.
6. Joe Reisert, W1JR, "VHF/UHF World-More Loose Ends," *Ham Radio*, September 1988, page 53.

Article E **HAM RADIO**

THE HAM NOTEBOOK

Crank-up tower cable guides

PHOTO A

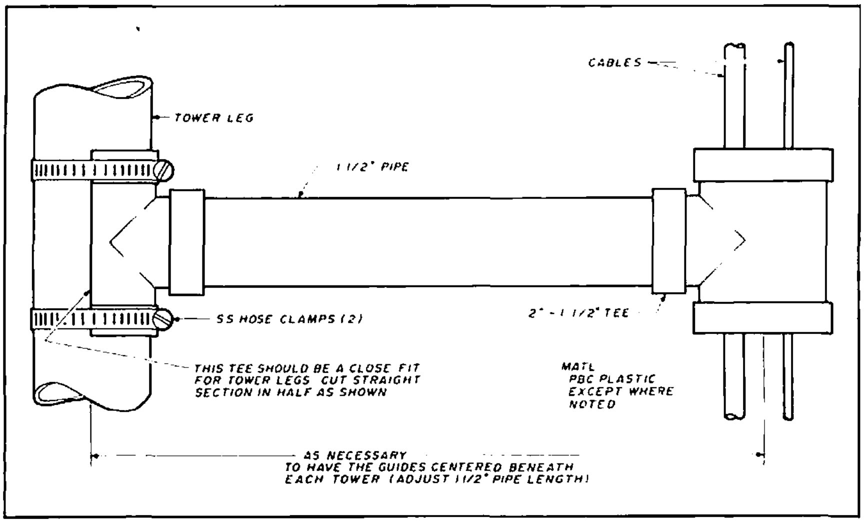


One of the cable guides installed on my tower.

When I set up my new crank-up tower, I installed the cable guides shown in **photo A** and **fig. 1**. Phil Malmberg, W4NOO, of Cocoa Beach, Florida designed the guides. He has used them successfully on his 60-foot crank up for years. The guides control the motion of the cables from the rotator and antennas. They prevent excess sway in the wind when the tower is cranked up and help make a neat pile at the foot of the tower when it's cranked down. Use two guides on the bottom tower section and one at the top of each movable section.

George Wilson, W1OLP

FIGURE 1

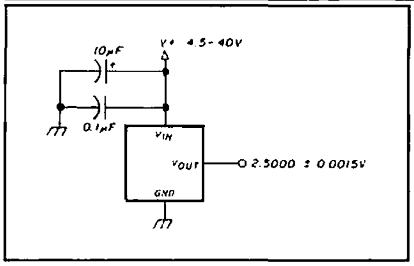


Details for assembling and installing the cable guides.

Simple inexpensive check for voltmeter accuracy

Do you have an old voltmeter that you'd like to check for accuracy or recalibrate? This can present problems if you don't have a standard cell or access to some other sophisticated test gear. Here's a simple inexpensive solution built around a Precision Monolithics REF 43F voltage reference IC.* (see **fig. 1**)

FIGURE 1



Schematic of a simple, high-accuracy voltage source.

The 43F is guaranteed to have a maximum error of 0.06 percent from its normal 2.50-volt reference point (i.e., between 2.4985 to 2.5015 volts). It will operate with a DC voltage source between +4.5 and +40 volts and supply a minimum of 10 mA into a load. The quiescent supply current at no load is 450 μA, maximum.

These characteristics indicate that the 43F can be run from a battery or power supply source, and that a precision voltage divider can be used to supply an output of less than 2.5 volts.

It's probably a good idea to put the unit in a small box to reduce the thermocouple effects on the leads and to prevent sudden temperature changes.

*The REF 43F is available from: Allied Electronics, 401 E. 8th Street, Fort Worth, Texas 76102. *Ed.*

Arthur L. Bachelor, M.D.

Article F

ANTENNA ARRAY PATTERNS
WITH A PERSONAL COMPUTER

By Dennis D. King, KC7MT, 2204 East 10225 South, Sandy, Utah 84092

Program generates data for tabular or graphic display

I have enjoyed many of the antenna articles presented in *Ham Radio* magazine, but a practical grasp of the basic dynamics of antenna patterns always remained elusive. "ARRAY" gives you hands-on experience in antenna array basics and ground effects.

The computer program, written in BASIC for an IBM PC compatible, runs in Microsoft BASIC. Commands are generic and the program is easily modified to work with other BASIC interpreters.

program description

The operator loads in the currents, phase relationships, and spacings of any number of elements. The elements can be either omnidirectional or half-wave dipoles. If desired a perfect ground plane can be located parallel to the array. Next, the operator enters the distance to the ground plane as well as the antenna polarization. The resulting antenna pattern is then calculated and plotted in BASIC graphics on the screen. Two automatically scaled plots are available — field strength, and a log plot showing 25 dB of the pattern. This flexible program can look at both the vertical and horizontal electric field patterns of a beam located a fixed distance above a ground plane. It is menu-oriented with continuous prompts. A parameter change section allows for quick substitutions of any parameter without reloading all of the array information.

Program speed varies with the number of elements chosen. Most plots take less than 30 seconds to calculate. The program was written to be compatible with IBM/Microsoft BASIC compilers; using a compiler can speed things up significantly.

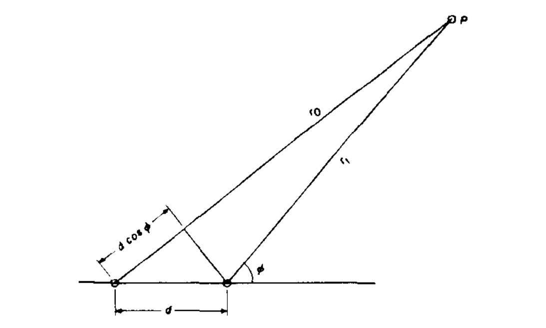
program construction

"ARRAY" is divided into several subroutines that perform different functions. The array pattern is calculated in a subroutine at line 490. The program computes the field strength at each angle by summing the E-field generated by each element of the array. The E-field contains both amplitude and phase information. **Figure 1** shows the geometry involved in calculating the field strength at a distant point P.

As you see in the drawing, if P is far enough away, r_0 and r_1 are almost the same length. Since the signal strength varies slowly as a function of 1/r, the relative signal strengths at P are proportional to the currents in the elements.

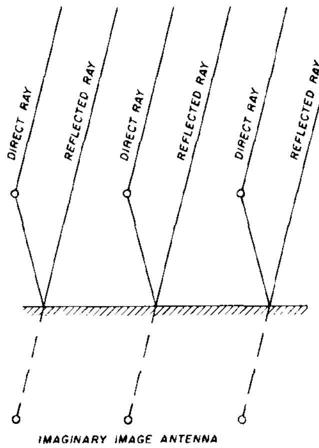
Phase changes rapidly with r — 360 degrees (2π radians) for every wavelength P is from an element. However, at P we are concerned only with the relative phase difference. **Figure 1** shows that the path length difference to P between two elements is d cos (ϕ). β is defined as the rate of phase change, where β = (2π/wavelength). The amount of phase difference is therefore $\beta d\cos\phi$. Now we must add one more factor — the phase difference between the original element currents (α). So the final equation for the phase difference between any two elements at point P is: phase difference $= \beta d\cos\phi + \alpha$ where $\beta = (2\pi/$ wavelength).

FIGURE 1



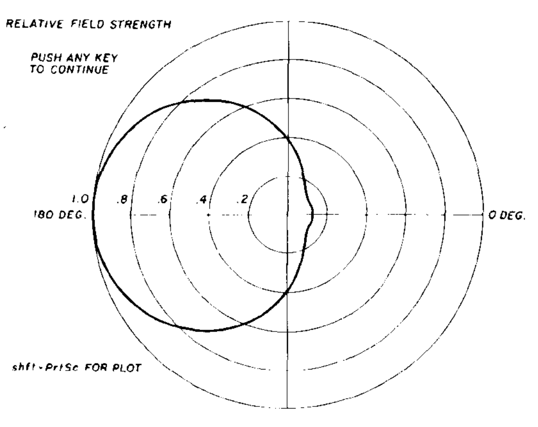
The geometry used with each element to calculate the field strength at point p.

FIGURE 2



Directed and reflected components from antenna elements. The latter appears to original form elements within the ground.

FIGURE 3



Three-element Yagi antenna pattern using omnidirectional elements.

For each radiation angle the program determines the relative magnitude and phase of each element, adds up the total, and places the result in array E. Because you can't add magnitude and phase in polar notation, the E-field values are first converted to rectangular coordinates, added, then reconverted back to polar magnitude.

Where elements are half-wave dipoles instead of omnidirectional elements, a factor is multiplied into each element to simulate the pattern and phase of dipole elements.

simulating ground effects

A ground plane relects the downward directed energy from the elements. At point P there are *two* components from each element: the direct path signal and the reflected path signal. **Figure 2** illustrates this geometrical relationship. While a routine could be incorporated to add the magnitudes and phases of all the signals as in the original array calculations, there is an easier process that uses the concept of an image antenna and the method of antenna pattern multiplication.

If an array at distance h above the ground is replaced with two identically driven arrays spaced 2h apart, the signals arriving at point P are the same in both cases. The second imaginary antenna is called the image antenna.

Pattern multiplication is another method of antenna analysis. All the elements of an array are replaced with a single point antenna having the array's pattern. The image antenna is also replaced by this single point antenna. There are now two antenna "elements" spaced vertically 2h apart. Calculate the pattern of these two omnidirectional elements using pattern multiplication. Simply multiply the pattern of this two-element vertical array with the pattern of the original horizontal array to produce the overall antenna pattern. This method is rigorously correct and significantly reduces computation time.

When an electromagnetic wave hits a perfectly conducting ground, the horizontal (or tangential) component of the E-field cannot exist (must equal zero). Consequently the reflected wave must have an equal value and opposite phase horizontal component to produce this "zero" result. In other words, in the reflection process the E-field phase is reversed by 180 degrees — similar to an incident wave in a coax encountering a short circuit. In a vertically polarized incident electromagnetic wave, the E-field is vertical and *not* shorted out by the conducting plane. The phase is not reversed upon reflection — similar to an incident wave in a coax encountering an *open* circuit. Therefore, the polarization of incident signals significantly affects the phase of the reflected signal. To compensate for this, the program adds 180 degrees

FIGURE 4

```
3  Element linear array

Element     magnitude        phase(DEG)  separation
 1              .662          0              n/a
 2             1              110.33         .15
 3              .5            244.5          .1

Array elements are omnidirectional.
Step size for analysis is currently  1  degrees.
Ground plane is  1  wavelengths below the array.
Array elements are horizontally polarized.

Do you want to change:
E-element parameters
G-toggle presence or absence of ground plane
P-toggle polarization of elements
H-change distance from array to ground plane
D-toggle omnidirectional elements or 1/2 wave dipole elements
S-change step size of analysis
A-analyze
```

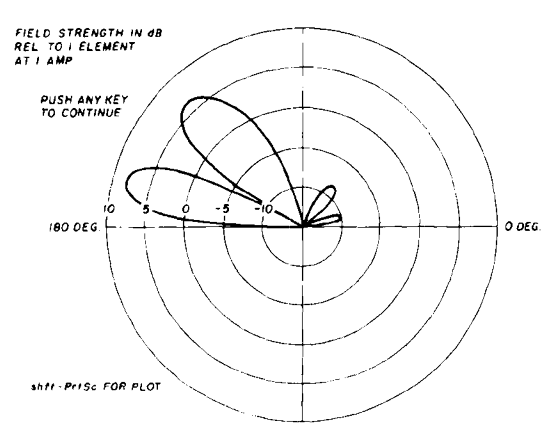
Screen display of change menu.

to the image antenna drive when the polarization is horizontal.

The "ARRAY" program assumes that the ground plane is an ideal conductor. In practice this is never true. The reflectivity of the earth is a function of the local complex dielectric constant (ε) for a given frequency. While it varies geographically, in general the lower the frequency the more ideal the earth appears. The reflectivity also varies with the incident angle. For horizontal polarization, the closer the angle is to the horizon, the closer the earth appears as an ideal conductor and the more accurate the program. Below 10 degrees or so it is virtually always accurate. For vertical polarization, the higher the angle is above the horizon, the more accurate the program. Something strange happens with vertical polarization at low angles. At angles below 20 degrees or so, the phase of the vertically polarized reflected wave is actually shifted 180 degrees, just as one would expect with horizontal polarization! As the angle increases, the reflected signal phase quickly shifts 180 degrees back to nearly 0. Therefore, for low angles, it is actually more realistic to model real-world vertical polarization patterns by specifying horizontal polarization. This is one reason why it is so important for a vertically polarized antenna to have a good ground plane if you want significant signal energy gain at low angles.

Even though the earth is not an ideal ground plane, the program is still useful in determining the location of peaks and nulls. In general, with the non-ideal earth, the location of the peaks and nulls will remain approximately correct but the amplitude of the peaks and depth of the nulls will be diminished.

FIGURE 5



A log plot of the vertical pattern of the 3-element Yagi mounted 1 wavelength above a ground plane.

plotting

Plotting routines are provided by lines 1150 and 1630. They are polar plotters converting the angle and magnitude to x,y coordinates and plotting the results on the screen. Both contain auto-scaling. The field strength plot routine scales the field strenth amplitudes so that the highest level is 1.0. The log plotter logs the data and scales it so that the highest 25-dB range is plotted.

FIGURE 6

The "ARRAY" program.

```
10 '**************************************************************
20 '!                        "ARRAY"                              !
30 '!           A linear array antenna pattern plotter            !
40 '!                   by Dennis D. King                         !
50 '!                     VERSION 1.0           11/87             !
60 '**************************************************************
70 'Main Program
80  DIM E(361),UNIT(361),L(361),M(25),THETA(25),D(25)
90  GOSUB 170       'Get input parameters
100  GOSUB 490       'Calculate field strength
110 GOSUB 3380      'Print main menu
120 A$=INKEY$:IF A$="" THEN 120 'Input menu choice
130 P=VAL(A$)
140 ON P GOSUB 1150,1630,2170,90,2740,2150
150 GOTO 110
160 '**************************************************************
170 'Getting input parameters
180 CLS:INPUT"How many elements in this linear array";E
190 CLS:PRINT"What is the magnitude of element 1 current"
200 PRINT"(1 amp is often convenient, it need only be relative)"
210 INPUT M(1)          'M(?) defines the element currents
220   FOR J=2 TO E
230       PRINT"What's the magnitude of element current ";J;" rel to element 1?"
240       INPUT M(J)
250       PRINT"What is the phase(in deg) of element ";J;" rel. to element 1?"
260       INPUT THETA(J)
270       PRINT"How many wavelengths from element ";J;" to element ";J-1;"?"
280       INPUT D(J-1)
290   NEXT J
300 CLS:PRINT:PRINT"Is each element:":PRINT"O-omnidirectional  or;"
310 PRINT"D-a half wave dipole"
320 A$=INKEY$:IF A$="" THEN 320
330 IF A$="o" OR A$="O" THEN EL=0:GOTO 360
340 IF A$="d" OR A$="D" THEN EL=1:GOTO 360
350 GOTO 300
360 CLS:INPUT"What step size in degrees for the anaysis";ST
370 CLS:PRINT:INPUT"Is there a ground plane beneath the array(Y/N)";A$
380 IF A$="Y" OR A$="y" THEN 400
390 GP=0:EEND=360:RETURN 'GP indicates existence of ground plane
400 GP=1:EEND=180
410 INPUT"How many wavelengths below the array is the ground plane";GPWL
420 PRINT:PRINT"Are the array elements:":PRINT"H-Horizontally polarized   or;"
430 PRINT"V-Vertically polarized?"
440 A$=INKEY$:IF A$="" THEN 440
450 IF A$="h" OR A$="H" THEN POL=0:RETURN
460 IF A$="v" OR A$="V" THEN POL=1:RETURN
470 GOTO 420
480 '**************************************************************
490 'Calculating field strength for each degree of angle
500 'Output is E(0-359)
510 CLS
520   FOR DEG=0 TO EEND STEP ST
530       LOCATE 12,25:PRINT"Working on ";DEG;" degree angle."
540       ANG=DEG/57.2975     'converts degrees to radians
550       CO=COS(ANG)
560       IF EL=1 THEN SI=SIN(ANG+1.5708):IF ABS(SI)<.001 THEN RT=0:GOTO 610
570        that statement defined sin(angle+90 degrees)for later
580       :IF EL=1 THEN GOSUB 1090:RT=M(1)*MDIP:GOTO 610
590 '     that statement defined the mag.of element pattern if dipole
600       RT=M(1)
610       IT=0:D=0
620         FOR I=2 TO E
630             D=D+D(I-1)
640             IF EL=1 AND ABS(SI)<.001 THEN MAG=0:GOTO 670
650             IF EL=1 THEN GOSUB 1090:MAG=M(I)*MDIP:GOTO 670
660             MAG=M(I)
670             THET=THETA(I)+6.283*D*CO*57.2975
680             GOSUB 1010 'changing mag and phase to rectangular
690             RT=RT+REAL:IT=IT+IM
700         NEXT I
710       REAL=RT:IM=IT
720       GOSUB 1060 'changing from rect back to polar
730       E(DEG)=MAG
740   NEXT DEG
750 IF GP=1 THEN GOSUB 780 'this does the ground plane calcs
760 RETURN
770 '--------------------------------------------------------------
780 'this sub accommodates ground plane in field
790 'generate image pattern
800  MAG=1:IF POL=0 THEN THETA=180 'accounts for phase of ref.due to polarity
810  IF POL=1 THEN THETA=0
820   FOR DEG=0 TO 360 STEP ST
830       CO=COS((DEG-90)/57.2975)'this rotates pattern -90 deg
840       D=2*GPWL
850       LOCATE 12,22:PRINT"Working on image pattern,";DEG;" degrees."
860       MAG=1:THET=THETA+6.283*D*CO*57.2975
870       GOSUB 1010 'polar to rect
880       RT=1+REAL:IT=IM
890       REAL=RT:IM=IT
900       GOSUB 1060 'changing rect to polar
910       UNIT(DEG)=MAG
920   NEXT DEG
930 'we now have image pattern
940 'multiplying image and array patterns
950   FOR DEG=0 TO EEND STEP ST
960       E(DEG)=E(DEG)*UNIT(DEG)
970   NEXT DEG
980 RETURN
990 '--------------------------------------------------------------
1000 'changing polar coordinates MAG AND THET to rectangular REAL AND IM
1010 REAL=MAG*COS(THET/57.2975)
```

```
1020 IM=MAG*SIN(THET/57.2975)
1030 RETURN
1040 '------------------------------------------------------------------
1050 'changes rectangular coordinates REAL AND IM to magnitude MAG
1060 MAG=(REAL^2+IM^2)^.5 'changes rectangular to magnitude
1070 RETURN
1080 '------------------------------------------------------------------
1090 'this sub returns a value MDIP which is the gain factor of dipole element
1100 MDIP=((COS(1.57*COS(ANG+1.5708)))/SI)
1110 RETURN
1120 '------------------------------------------------------------------
1130 '
1140 '******************************************************************
1150 'plotting field strength data
1160 SCREEN 2:CLS
1170 CIRCLE (320,100),239
1180 CIRCLE (320,100),192
1190 CIRCLE (320,100),144
1200 CIRCLE (320,100),96
1210 CIRCLE (320,100),48
1220 LINE (80,100)-(560,100)
1230 LOCATE 23,1:PRINT"shft-PrtSc for plot"
1240 LOCATE 3,2:PRINT"Push any key"
1250 LOCATE 4,2:PRINT"To continue"
1260 LINE (320,0)-(320,200)
1270 LOCATE 13,72:PRINT"0 deg"
1280 LOCATE 12,10 :PRINT"1"
1290 LOCATE 12,15:PRINT ".8"
1300 LOCATE 12,21:PRINT".6"
1310 LOCATE 12,27:PRINT".4"
1320 LOCATE 12,33:PRINT".2"
1330 LOCATE 1,2:PRINT"Relative Field Strength"
1340 LOCATE 13,3:PRINT"180 deg."
1350 GOSUB 1470 'sizing data, finding min and max
1360 SCALE=1/MAX 'scale factor to make max=1
1370 X1=320:Y1=100
1380   FOR DEG=0 TO EEND STEP ST
1390      M=SCALE*E(DEG):A=DEG
1400      GOSUB 1550
1410      LINE (X1,Y1)-(X,Y) 'draws lines between x1 y1 points
1420      X1=X:Y1=Y
1430   NEXT DEG
1440 A$=INKEY$:IF A$="" THEN 1440
1450 RETURN
1460 '------------------------------------------------------------------
1470 'this sub sizes the data, finds min and max
1480 MIN=1000000!:MAX=-1000000!
1490   FOR DEG=0 TO EEND STEP ST
1500      IF MAX<E(DEG) THEN MAX=E(DEG)
1510      IF MIN>E(DEG) THEN MIN=E(DEG)
1520   NEXT DEG
1530 RETURN
1540 '------------------------------------------------------------------
1550 'this sub returns x,y coordinates for unit plot
1560 'given inputs of magnitude M and angle A in degrees
1570 X=320+240*M*COS(A/57.2975)
1580 Y=100-100*M*SIN(A/57.2975)
1590 RETURN
1600 '------------------------------------------------------------------
1610 '
1620 '******************************************************************
1630 'Plotting in dB the highest 25 db of magnitude data
1640 GOSUB 1990 'logging data
1650 GOSUB 2080 'determines scale
1660 SCREEN 2:CLS
1670 CIRCLE (320,100),239
1680 CIRCLE (320,100),192
1690 CIRCLE (320,100),144
1700 CIRCLE (320,100),96
1710 CIRCLE (320,100),48
1720 LINE (80,100)-(560,100)
1730 LOCATE 23,1:PRINT"shft-PrtSc for plot"
1740 LOCATE 5,2:PRINT"Push any key"
1750 LOCATE 6,2:PRINT"To continue"
1760 LINE (320,0)-(320,200)
1770 LOCATE 13,72:PRINT"0 deg"
1780 LOCATE 12,10 :PRINT OUTRING
1790 LOCATE 12,15:PRINT OUTRING-5
1800 LOCATE 12,21:PRINT OUTRING-10
1810 LOCATE 12,27:PRINT OUTRING-15
1820 LOCATE 12,33:PRINT OUTRING-20
1830 LOCATE 1,2:PRINT"Field Strength in db "
1840 LOCATE 2,2:PRINT"Rel to 1 element"
1850 LOCATE 3,2:PRINT"At 1 amp"
1860 LOCATE 13,3:PRINT"180 deg."
1870 SCALE=1/25
1880 X1=320:Y1=100
1890   FOR DEG=0 TO EEND STEP ST
1900      M=SCALE*((L(DEG)-OUTRING+25)):A=DEG 'this scales data
1910      IF M<0 THEN M=0
1920      GOSUB 1550
1930      LINE (X1,Y1)-(X,Y)
1940      X1=X:Y1=Y
1950   NEXT DEG
1960 A$=INKEY$:IF A$="" THEN 1440
1970 RETURN
1980 '------------------------------------------------------------------
1990 'this sub changes the data to db's rel to single element
2000 MIN=1000000!:MAX=-1000000!
2010   FOR DEG=0 TO EEND STEP ST
2020      IF E(DEG)=0 THEN L(DEG)=-100:GOTO 2040
2030      L(DEG)=8.686*LOG(E(DEG))
```

```
2040       IF MAX<L(DEG) THEN MAX=L(DEG)
2050       IF MIN>L(DEG) THEN MIN=L(DEG)
2060    NEXT DEG
2070 '-------------------------------------------------------------------
2080 'this sub determines the scale
2090 OUTRING=5*INT(MAX/5)+5 'outring is the nearest 5db increment
2100 CENT=OUTRING-25
2110 RETURN
2120 '-------------------------------------------------------------------
2130 '
2140 '*******************************************************************
2150 SYSTEM 'sends execution back to dos
2160 '*******************************************************************
2170 'printing out data
2180 CLS:GOSUB 1990 'logging data
2190 PRINT"Do you want to:":PRINT" S-print on screen":
2200 PRINT" P-print out on printer"
2210 PRINT" Q-quit"
2220 A$=INKEY$:IF A$="" THEN 2220
2230 IF A$="s" OR A$="S" THEN GOSUB 2460
2240 IF A$="p" OR A$="P" THEN GOSUB 2580
2250 IF A$="q" OR A$="Q" THEN RETURN
2260 GOTO 2170
2270 '------------------------------------------------------------------
2280 'this sub prints the parameters on the screen
2290 PRINT:PRINT E;" Element linear array":PRINT
2300 PRINT"Element     magnitude        phase(DEG)   separation"
2310 PRINT" 1",M(1)," 0                n/a
2320    FOR I=2 TO E
2330       PRINT I,M(I),THETA(I),D(I-1)
2340    NEXT I
2350 PRINT
2360 IF EL=0 THEN PRINT"Array elements are omnidirectional."
2370 IF EL=1 THEN PRINT"Array elements have 1/2 wave dipole pattern."
2380 PRINT"Step size for analysis is currently ";ST;" degrees."
2390 IF GP=1 THEN 2410
2400 RETURN
2410 PRINT"Ground plane is ";GPWL;" wavelengths below the array."
2420 IF POL=0 THEN PRINT"Array elements are horizontally polarized."
2430 IF POL=1 THEN PRINT"Array elements are vertically polarized."
2440 RETURN
2450 '-------------------------------------------------------------------
2460 CLS'printing out on screen
2470 GOSUB 2280 'prints out parameters
2480 PRINT:PRINT"ANGLE       FS(VOLTS)     REL GAIN TO 1 ELEMENT(DB)
2490 PRINT
2500    FOR DEG=0 TO EEND STEP ST
2510       PRINT DEG,E(DEG);TAB(31) L(DEG)
2520    NEXT DEG
2530 PRINT"Hit any key to continue"
2540 B$=INKEY$:IF B$="" THEN 2540
2550 RETURN
2560 '-------------------------------------------------------------------
2570 'printing out on printer
2580 CLS:PRINT"Sending to printer"
2590 LPRINT E;" Element linear array":PRINT
2600 LPRINT"Element     magnitude        phase          separation"
2610 LPRINT" 1               1                0                N/A"
2620    FOR I=2 TO E
2630       LPRINT E,M(I),THETA(I),D(I-1)
2640    NEXT I
2650 LPRINT:LPRINT"ANGLE       FS(VOLTS)     REL GAIN TO 1 ELEMENT(DB)
2660 LPRINT
2670    FOR DEG=0 TO EEND STEP ST
2680       LPRINT DEG,E(DEG);TAB(31) L(DEG)
2690    NEXT DEG
2700 RETURN
2710 '-------------------------------------------------------------------
2720 '
2730 '*******************************************************************
2740 'change parameters
2750 GOSUB 2280 'prints out current parameters
2760 PRINT:PRINT"Do you want to change:"
2770 PRINT"E-element parameters"
2780 PRINT"G-toggle presence or absence of ground plane
2790 PRINT"P-toggle polarization of elements
2800 PRINT"H-change distance from array to ground plane
2810 PRINT"D-toggle omnidirectional elements or 1/2 wave dipole elements"
2820 PRINT"S-change step size of analysis"
2830 PRINT"A-analyze"
2840 A$=INKEY$:IF A$="" THEN 2840
2850 IF A$="e" OR A$="E" THEN GOSUB 2990
2860 IF A$="g" OR A$="G" THEN GOSUB 3160
2870 IF A$="p" OR A$="P" THEN GOSUB 3210
2880 IF A$="h" OR A$="H" THEN GOSUB 3260
2890 IF A$="a" OR A$="A" THEN CLS:GOTO 100
2900 IF A$="d" OR A$="D" THEN GOSUB 3310
2910 IF A$="s" OR A$="S" THEN GOSUB 2940
2920 CLS:GOTO 2750
2930 '------------------------------------------------------------------
2940 'changes step size of analysis
2950 CLS:PRINT"Step size is currently ";ST; "degrees."
2960 INPUT"What new step size in degrees";ST
2970 RETURN
2980 '------------------------------------------------------------------
2990 'changes element parameters
3000 CLS:INPUT"Which element to change";R
3010 CLS:PRINT:PRINT"element      magnitude        phase(deg)     separation"
3020 PRINT R,M(R),THETA(R),D(R-1)
3030 PRINT
3040 PRINT"Do you want to change:"
3050 PRINT"M-magnitude"
3060 PRINT"P-phase":PRINT"S-separation in wavelengths"
```

```
3070 PRINT"F-finished"
3080 A$=INKEY$:IF A$="" THEN 3080
3090 IF A$="m" OR A$="M" THEN INPUT"What is new magnitude";M(R):GOTO 3010
3100 IF A$="p" OR A$="P" THEN INPUT"What new phase(in deg)";THETA(R):GOTO 3010
3110 IF A$="s" OR A$="S" THEN INPUT"What new separ.(in wvltns)";D(R-1):GOTO 3010
3120 IF A$="f" OR A$="F" THEN RETURN
3130 GOTO 3010
3140 RETURN
3150 '--------------------------------------------------------------
3160 'toggles presence of ground plane
3170 IF GP=1 THEN GP=0:EEND=360:RETURN
3180 IF GP=0 THEN GP=1:EEND=180:RETURN
3190 RETURN
3200 '--------------------------------------------------------------
3210 'toggles polarization of elements
3220 IF POL=0 THEN PCL=1:RETURN
3230 IF POL=1 THEN PCL=0:RETURN
3240 RETURN
3250 '--------------------------------------------------------------
3260 'changes distance from ground
3270 PRINT
3280 INPUT"What is new distance from array to ground in wavelengths";GPWL
3290 RETURN
3300 '--------------------------------------------------------------
3310 'toggles omni or dipole element patterns
3320 IF EL=1 THEN EL=0:RETURN
3330 IF EL=0 THEN EL=1:RETURN
3340 RETURN
3350 '--------------------------------------------------------------
3360 '
3370 '**************************************************************
3380 'This sub prints the main menu
3390 CLS:PRINT"Do you want to :":PRINT" 1-plot field strength data"
3400 PRINT " 2-plot data in db"
3410 PRINT " 3-print out data":PRINT" 4-start over"
3420 PRINT" 5-Change Parameters":PRINT" 6-quit"
3430 RETURN
3440 '**************************************************************
```

printing

The calculated patterns can be displayed on the screen or sent to a printer. The output contains each data point in both field strength and dB.

changing parameters

The change parameters routine, located at line 2740, is most worthwhile feature of "ARRAY". It allows the operator to change any of the antenna parameters easily and analyze the new data quickly.

BASIC compatibility

These are the only non-generic basic statements used: "Screen 2", which places Microsoft BASIC in high resolution graphics mode; "LINE", which draws lines between two screen coordinates; and "CIRCLE", which draws a circle of a given radius at a designated screen location. The plot routines are written around standard IBM graphics providing a resolution of 640 by 200. These commands should be easily adaptable for noncompatible forms of BASIC. The circles routine is not essential.

example

There have been some great articles in *Ham Radio* on Yagi antennas. While somewhat difficult, it is possible to derive the driven and induced currents in a Yagi array. Walter Schulz[2] described a three-element Yagi and calculated the element currents. Since the log plotter in the program uses 1 A in one element as a reference for 0 dB, the element currents are scaled so that the driver current is 1 A. The values for this three-element Yagi are:

Element	Current	Rel Phase	Separation in wavelengths
1	0.662	0	N/A
2	1.0	110.33	.15
3	0.5	244.5	.1

The program can first look at the vertical (from the side) field strength pattern in free space. Omnidirectional elements are used because each dipole element appears omnidirectional from the side of the Yagi.

Figure 3 is the resulting field strength plot. An ideal ground plane can now be added. Assume the Yagi is horizontally polarized and mounted 1 wavelength off the ground. (This is equivalent to 65 feet for a 20-meter beam.)

Figure 4 is the menu displayed for adding the ground plane and associated parameters.

Figure 5 shows the resulting field strength plotted with the log plot routine. On the plot, 0 dB is the field strength that one element in free space would have with the same drive current of 1 A. On 20 meters the Yagi's primary lobe fires upward about 14 degrees.

conclusion

The "ARRAY" program, **fig. 6**, was primarily developed as an educational tool and will help anyone with a personal computer gain insight into antennas and resulting patterns. I'd be interested in receiving any comments, corrections to the program, or suggestions on possible improvements.

A written copy with comments and a 5-1/4 inch MS-DOS DSDD floppy containing the program is available from the author for $15.00.

reference

1. Walter Schulz, Jr., "Key to 3-Element Yagi Design," *Ham Radio*, March 1984, pages 48-51.

bibliography

Edward Jordan, Keith Balmain, "Electromagnetic Waves and Radiating Systems," Prentice-Hall, Inc., 1968.

Article G **HAM RADIO**

A 220-MHZ 9600-BAUD DATA RADIO SYSTEM FOR PACKET

By Fred B. Cupp, W2DUC, 27 Crescent Road, Fairport, New York 14450

Techniques, equipment, and software for Amateur Packet Radio evolved in response to the medium's emerging needs. In packet's early days, the development of a dedicated controller, or TNC, presented a major stumbling block. Once this problem was overcome, the TNC was used with conventional 2-meter FM radios and telephone-type 1200-baud modems to get stations on the air and communicating.

The Packet Bulletin Board System, or BBS, was the next innovation. The WØRLI operating system, developed for the Xerox 820 computer board, has set a "de facto" standard for BBS software running on other machines — usually an IBM PC or clone. These BBS's have made mail forwarding on VHF a practical reality. They serve as local information centers and Amateur electronic mail networks.

Now there's interest in the formation of true electronic networks which will use intelligent node controllers to handle the traffic between distant stations automatically. There are still many questions to be answered, but at least three distinct groups are working on particular networking methods. But in the midst of all this activity, there's one item which seems to have been overlooked.

Dedicated high-speed radio links will be needed for network support, no matter what protocol finally emerges as the standard. There have been several complete radio modems advertised in ham magazines recently, but the cost of these units is rather steep compared to what we pay for the rest of our packet gear. In search of a low-cost alternative, N2AMK and I began experimenting with high-speed packet in the spring of 1987. Here are the methods and equipment we tried for running 9600 baud on 220 MHz using modified commercially available equipment.

One of the ways used to encode digital data on an RF carrier, Audio Frequency Shift keying (AFSK), is rather wasteful of bandwidth. Audio Phase Shift Keying (APSK) is better, but still isn't the ultimate. Current literature indicates that direct frequency modulation of the carrier by a digital signal is the most *efficient method,* especially in the presence of noise as the signal gets weaker.

To reduce the bandwidth of the transmission, you can filter the digital signal to limit the spectrum without significantly reducing the effectiveness of the received signal. Actually, this may be considered "rate-limited frequency shift keying." The trick is in the receiving end, where it's necessary to establish references for decoding the digital signal and regenerating the original TTL level signals.

For more information read "The TEXNET Packet Switching Network-part 2," published in *Ham Radio,* April 1987. Another good reference is the paper by Steve Goode, K9NG, in the fourth ARRL networking conference book. These articles provide good background on digital transmission and the problem of envelope or group delay. We've also included our own "Layman's Guide to Data Transmission" at the end of this article.

Group delay is also called "frequency/phase nonlinearity." Simply stated, digital signals are comprised of a variety of frequencies depending on the number of "ones" and "zeros" in the data stream. If the higher frequencies pass through the system with different time delays than the lower frequencies, the clock recovery and the decoding of the bit stream will be poor. There are two possible methods of correction.

The first method (used in TEXNET) is to insert frequency-variable time-delay circuits in the receiver

output to correct or compensate for the distortion caused by the receiver IF filters. The second is to use a class of filters which have been designed for "flat" group delay. The advantage in using the second method is that it doesn't require adjustment to match the particular receiver IF.

We looked through several manufacturers' catalogs and found a class of IF filter intended for use in the digital control links of cellular telephones. The filters are produced by Murata-Erie, which also manufactures the filters used in the Hamtronics radios. The filter pinout and physical size are identical.

Armed with some sample filters, we got our project underway and built two systems – one at W2DUC, another at N2AMK. The test path was about 18 miles and over enough hills to require 10-watt "afterburners," especially during the summer when the trees were in leaf.

Design goals

In planning our tests, we decided not to use surplus equipment because we couldn't be sure others would be able to find the same parts. Instead, we used relatively standard parts and easy-to-obtain modules. Modular units let you make modifications without reworking a large unit.

Because we wanted a system that could be set up with a minimum of special test equipment, we had to keep the number of adjustments to a minimum.

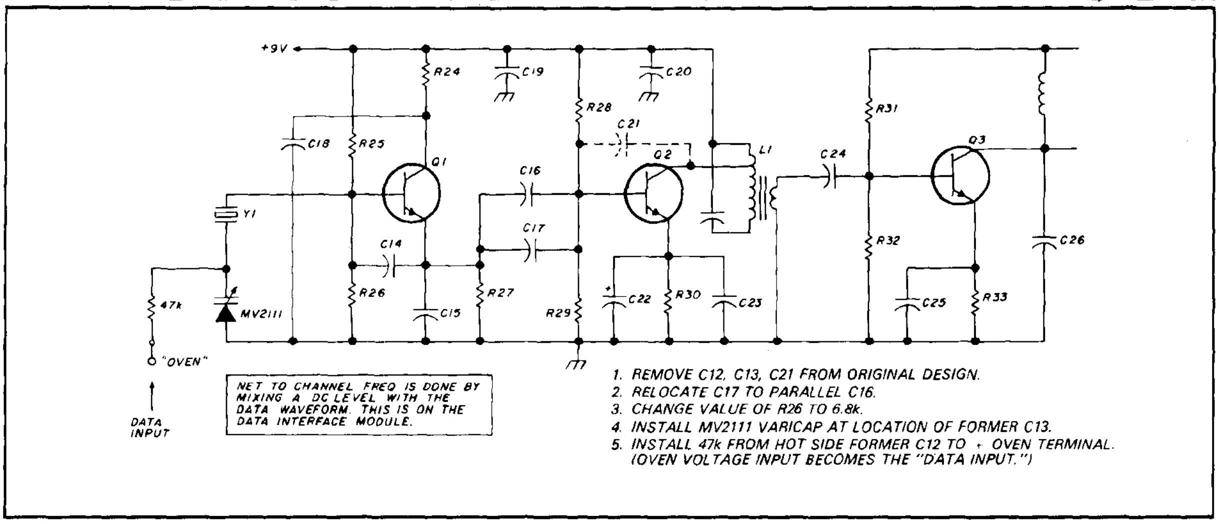
Although TEXNET used the Hamtronics FM-5 transceivers, they've received some poor reviews when used in 9600-baud links. After talking with WA2GCF, Jerry Vogt of Hamtronics, we decided to choose separate modules for the exciter and receiver. These modules were better suited to the modifications we wanted to perform and were more stable than the earlier FM-5.

Our plan was to remove the phase modulator in the Hamtronics TA-51 exciter module. FM modulation is obtained by using a voltage variable capacitor (varicap) in the crystal oscillator circuit. Netting to frequency is achieved by summing the data with a DC voltage. You can use the optional speech input, as well as the digital data.

The receiver was very nearly "stock." We modified the squelch circuit to remove the hysteresis. The squelch signal was brought out to be used as the carrier detect input to the TNC. The discriminator output was brought out to the modem board, with the receiver audio left intact for voice use. For packet operation, simply turn down the volume control.

For the application in this article it's assumed that you are modifying a completely assembled pair of modules. If you're building a new kit, simply leave out the parts mentioned in the following changes.

FIGURE 1



Changes to Hamtronics TA-51 220-MHz exciter for 9600-baud data transmission.

Exciter module changes

The exciters (from Hamtronics, Inc.) were originally built in the normal voice form. The radios were then tested on voice to assure proper operation. We discovered that the path was a little too rough and built a pair of 10-foot homebrew Yagis, which brought the signals up to usable voice quality. While some 9600-baud operation was possible, there was still enough noise on the signal to prevent perfect transmissions without retries. The 2 watts of the exciters just wasn't enough.

Adding the power amplifiers solved all the signal strength problems and also took care of the antenna switching (originally external to the modules). Antenna switching is included in the power amplifier modules.

As mentioned earlier, the major change was the conversion from phase modulation to direct FM. In the original circuit, Q2 was the phase modulator. The RF signal had two possible paths, one through Q2 and the other through capacitor C21. Varying the bias on Q2 caused a variation in the contribution of the two paths, which in turn caused a variation in the phase of the RF. Q2 was converted to a straight-through buffer by removing C21. C17 was part of a voltage divider in the drive path to Q2. This was relocated to *parallel* C16, increasing the drive to the stage (see **fig. 1**).

We modified the oscillator by removing two capacitors which were in series with the crystal to ground and installed an MV2111 varicap in place of C13. A 47-k resistor connected to the junction of the crystal and the varicap provides the injection of the control voltage. We used a terminal normally used with the crystal oven as a connection point for the 47-k resistor and the incoming control signal.

Because we were operating the radios inside a heated ham shack, we didn't need the optional crystal ovens. However, you should use them in hilltop applications. In this case you need some other means of connecting to the 47-k resistor. (You can solder a terminal strip to the underside of the pc board near the oscillator circuit.)

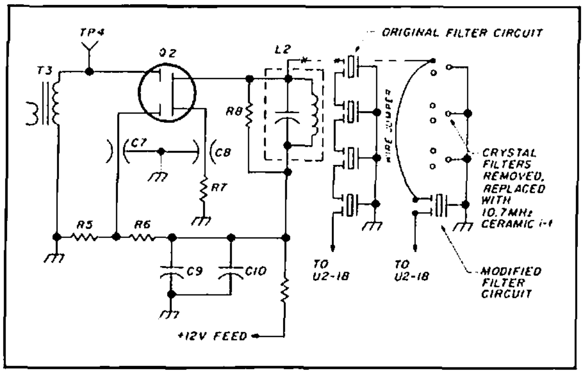
Initial netting to the desired frequency must be done without the data connected to the modem board. If the voice option is available, just switch to voice; this will leave a carrier for setting the frequency. If you don't use a switch, disconnect (leave open) the data input.

The final modification involves bringing out the audio signal from the microphone preamp to the voice-data switch. Remove R21, the first resistor in the audio roll-off filter. (You may insert a wire in the now empty pad which connects to C9.) This picks up the signal at the deviation control. To get full deviation on voice, we raised the clipping level by changing R10 to a 3.3-k resistor.

Receiver module changes

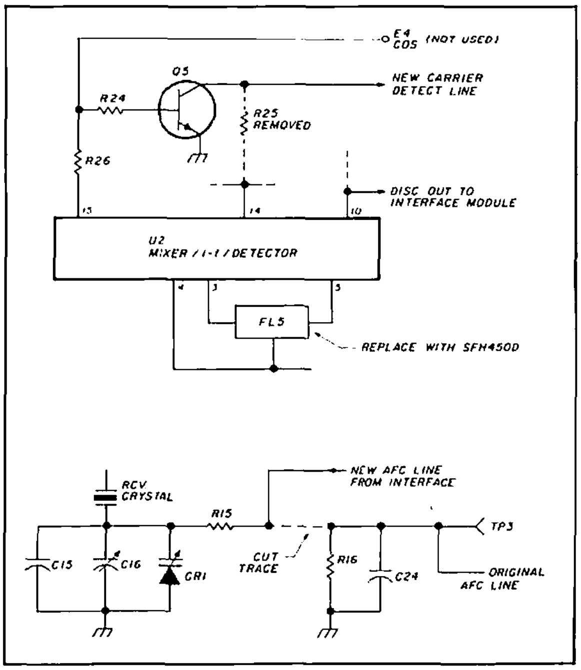
The receiver modifications are made primarily to correct the group delay in the IF strip. We performed several tests to determine the necessity of changing both the 10.7-MHz crystal filters and the 455-kHz IF filter. We tried several combinations of crystal filters with very poor results. It's necessary to increase the 10.7-MHz IF bandwidth by replacing the crystal filters with a conventional FM broadcast-type IF ceramic filter. The original filter consists of four crystal filters (FL1 through FL4), so you must use a wire jumper to bridge across the three empty positions that remain. (See **fig. 2.**)

FIGURE 2



Partial schematic of 10.7-MHz filter change.

FIGURE 3

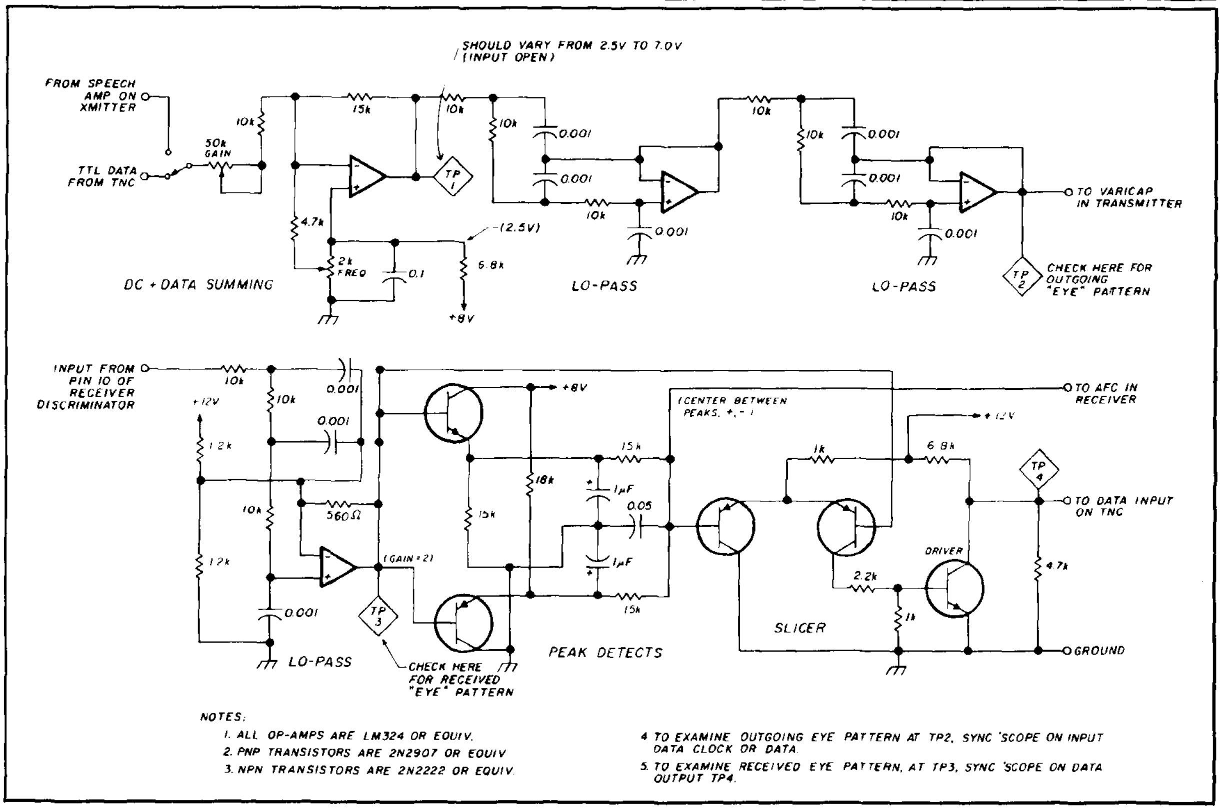


Partial schematic of receiver-module changes.

We replaced the 455-kHz second IF (FL5) with the Murata-Erie digital IF filter. This unit has a center frequency of 450 kHz instead of the conventional 455 kHz. We encountered no problems netting to frequency, because the 5-kHz difference was well within the "tweaking" range of the receive crystal trimmer. This filter fits the Hamtronics board with no modifications. (See **fig. 3.**)

Next, unsolder and lift the end of R15 at the junction with C24 and R16. This disables the normal AFC. Connect the "fast" AFC (terminal E6) from the modem board to the open end of R15. The direction of AFC action is right for centering an incoming signal. A wire

FIGURE 4



Schematic of 9600-baud packet radio interface.

from pin 10 of the discriminator (U2) brings the FM output to the modem board, terminal E4.

Finally, remove R25 in the squelch circuit. This leaves the collector of Q5 open. Connect a wire from the collector to the squelch input of the TNC. This will operate the carrier detect light on the TNC and hold back transmission when the channel is busy.

The various receiver connections won't inhibit normal receiver use for either data or voice. The squelch action will, however, be "softer" because there's no longer any hysteresis in the detector.

Modem board

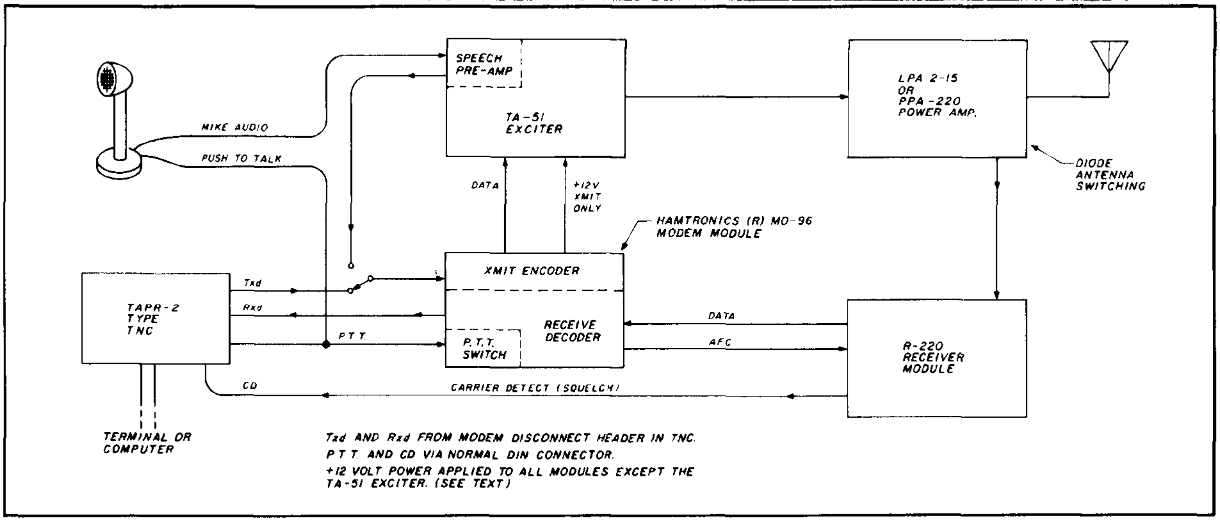
Figure 4 is a schematic diagram of the modem or interface between the TNC and the radio. As you'd expect, there are two distinct sections — the transmit encoder and the receive decoder.

The transmit section uses three sections of a quad op amp, (LM-324). The first stage combines the data or optional voice signal with the DC offset voltage. Varying the frequency adjust pot setting shifts the bias or center value of the output voltage. This then establishes the carrier center frequency. The fixed voltage at the noninverting input is +2.5 volts; when data is applied (5-volt logic levels) it will shift the output of the op amp equally above and below the desired output point. This causes an equal carrier shift above and below the center frequency.

The signal at TP1 is still a square wave, so two stages of active low-pass filtering follow. After filtering, the output at TP2 will be nearly sinusoidal in shape. This reduces the bandwidth of the transmitted signal. The DC level injected at the first stage is unaffected by the filters and also serves as the filter bias. The signal at the output is next applied to the varicap in the transmitter circuit, through a series resistor. The nominal voltage at TP2 will be about 5-6 volts with ± 2 volts deviation when data is present.

The receive section is a bit more complex. The output of the receiver discriminator is first applied to another filter similar in function to those used in the transmit section. The intent is to reduce the bandwidth of the received audio, removing high-frequency noise which would interfere with data decoding. A gain-adjusting resistor is added to the network to boost the signal level by a factor of 2. This raises the low signal level from the discriminator output to improve the operation of the level detectors.

FIGURE 5



Block diagram of complete packet radio system.

Two transistors are used as peak level detectors. The NPN "follows" the positive excursions of the signal, charging up the 1-μF capacitor to near the peak positive value. In like manner, the PNP follows the negative peaks, charging another 1-μF capacitor. The discharge time constant is equal to about 20 bit periods at 9600 baud. A pair of equal (15 k) resistors bridges the two level detectors. The voltage at the center tap of the resistors is the value of the midpoint between the two peaks.

This voltage serves two purposes. Because it has a very fast attack and represents the center of the modulation swings, it can be applied to the AFC circuit in the R-220. This helps the receiver to center rapidly on an incoming signal during the preamble or "flags" period.

The voltage is also used as a reference voltage applied to one input of a differential comparator or "slicer," using two PNP transistors. With the reference applied to one input and the raw data signal applied to the other, the resulting output is a digital representation of the instantaneous received signal frequency. The signal is buffered and shaped to TTL logic level by the NPN transistor and the resistive voltage divider. Note that this isn't an RS-232 signal, but a logic level to be applied to the external modem connector of the TNC.

System interconnections

Figure 5 is a block diagram of the complete system showing the Hamtronics modules, the interface or modem board, and the interconnections to the TNC. The TNC must have a modem disconnect header or connector. It must also be set for 9600-baud operation. The RS-232 port from the TNC isn't shown; it may be operated at whatever data rate you desire.

Twelve-volt power is applied to all of the modules except the exciter. Because the power amplifier module is class C, it isn't necessary to switch the power — only the drive. When the TNC pulls down on the PTT line, the transistor switch on the modem board applies the 12 volts to the exciter. This drives the power amplifier into conduction, drawing current from the 12-volt supply, which in turn operates the diode antenna switch.

The receiver module is powered at all times. When you transmit, your signal will be received, decoded, and passed back to your TNC. This permits a built-in "loopback test" function. Depending on the cable layout and the isolation of the T/R diode switching, you may have enough overload on the receiver to prevent clean reception of your own signal. Usually a good match to the antenna, decent cable connections, and grounding of all modules will tame any overload.

We brought the microphone preamp on the Hamtronics TA-51 exciter out to a switch and wired it to select either data or voice signal. The push-to-talk switch on the mike is wired in parallel with the PTT line from the TNC. This provides a voice mode which we used as an "intercom" during testing. This may even be helpful in a remote backbone digipeater situation, for use during setup and maintenance visits.

Summary — where do we go from here?

In the year that our on-the-air testing has been in

progress, there has been little published on the topic of higher speed packet operation. Everyone seems to be waiting to see what sort of equipment will emerge as the de facto standard. It seems that no one wants to be the first kid on the block to jump in. There are a few group efforts under way, but little information of a solid technical nature has appeared to let us know what's going on.

The system we've described here is a "Minimum Shift, Bandwidth Limited, Frequency Modulation System." Although I have not contacted AEA or GLB, an examination of their spec sheets indicates use of a very similar modulation method. The data rate is higher, so the bandwidth is wider but still in the same general relationship.

Naturally, each designer begins with a set of assumptions and builds from there. We assumed 9600 baud, since a standard (unmodified) TAPR-2 TNC will run only that fast. It can be pushed up by altering the taps on the clock divider, but we felt 9600 baud without cutting into the TNC would be attractive to most hams.

We arbitrarily chose a bandwidth of 8-10 kHz as a compromise. It's approximately the lower limit of Shannon's rule of thumb (1 Hz/bit/sec of bandwidth) and at reasonable "Amateur" signal-to-noise ratios. We also considered the availability of the Murata-Erie IF filters. Because the signal isn't crowded into a very narrow filter, phase distortion isn't a serious problem and frequency stability is less critical. In a year of operation, we haven't had to adjust the frequency of either unit.

We also considered the inclusion of a data "scrambler/descrambler" to reduce the DC content of the data signal. This lessens the tendency of the level detector or slicer to shift during periods of DC unbalance. In testing, the bit stuffing done by the TNC appeared to be adequate to survive even deliberate long strings of null characters or FFs in transparent mode. If you're a purist, you can still add a shift register scrambler in the data lines at each end of the circuit.

The standards we chose are loose enough to permit some latitude in matching to other system standards, within reasonable limits. We'd like to have an opportunity to see if our system is truly compatible with a GLB or AEA running at 9600 baud and with some similarity in the deviation. It should fly, but we won't know until we have a chance at one.

Just as I was finishing this article, I received the May 27th issue of the *Gateway*, volume 4, no. 18. It contains the specifications for the 9600-baud modem project, designed by James Miller, G3RUH. I was most interested in comparing the standards he used with the standards we have described. It appears that the approach is very similar. The major difference is that we have a "cheapie" version — sort of a Model T compared to a Cadillac.

The modulation scheme is identical. Direct FM is applied to a varactor diode. Miller shaves the deviation a little tighter, using 3-kHz deviation as opposed to the 4 kHz we used. The bandwidth low-pass filtering is done with a very classy digital "finite impulse response" transversal filter. While it's very sharp on the sides, the cut-off frequency is also 4800 Hz. He also included a shift register scrambler to remove any long strings of zeros or ones. Another interesting difference is the use of precompensation (or predistortion in the opposite direction), to correct the system phase distortion at the transmitter instead of the receiver.

Up to this point, the differences are quite minimal. The major difference seems to be in the complexity of the respective systems. I certainly agree that the super high-quality filters and digital PLL clock detectors can do nothing but improve performance. Our intent was to break some fresh ground and get some action started in 9600-baud networking. It will be interesting to check out our system in real over-the-air tests with the G3RUH modem. From the standpoint of compatibility, they should get along fine together.

Naturally, it's our hope that some packeteers in our area, or our neighbors in Canada, might try some tests with us. We've passed thousands of bytes of data back and forth, but it sure would be nice to do more than tests!

In conclusion, we want to thank Jerry Vogt, WA2GCF, of Hamtronics for his help on the modifications to the transceivers and for making pc boards available. Murata-Erie was also helpful in supplying several different filters, permitting a choice of the best bandwidth for this data rate.

The following modules are available from Hamtronics, Inc., 65 Moul Road, Hilton, New York 14468-9535, (716)392-9430.

MO-96 Packet Radio Networking Modem Module
TA-51-220-HS High-speed Data Exciter Module
R-220-HS High-speed Data Receiver Module
LPA 2-15 (220) 15-watt PA Module with diode antenna switch
PPA-220 50-watt Packet PA Module with pin diode antenna switch

Appendix A

Layman's (simplified) guide to data transmission

The following is admittedly not technically correct, but is presented to help you understand the basic methods used in transmitting data on VHF radio. Sig-

nal preparation will be shown up to the point of application to the FM modulator, and then as received from an FM discriminator or PLL detector.

If a random data signal is displayed on a scope and triggered at the bit rate, successive sweeps will overlap, creating what is known as an "eye" pattern. This pattern serves as a means of estimating the quality of the transmission/reception system, or path.

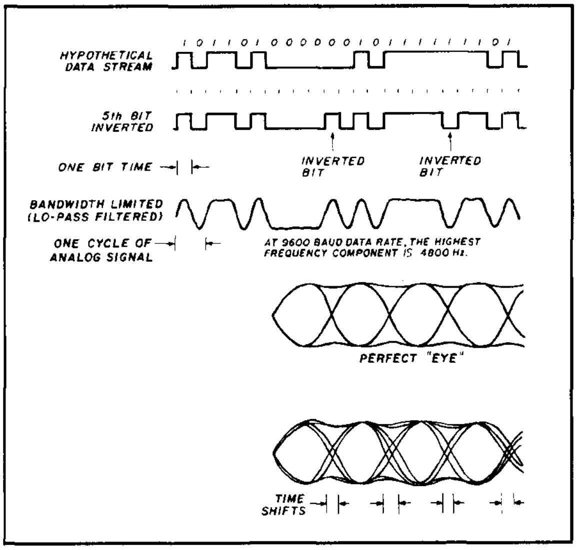
To determine whether a signal represents a "one" or a "zero," you must make a decision at a time interval related to past zero crossings. The absence or presence of zero crossings at the bit intervals indicates a change of the digital state. There are other more sophisticated methods for making the decision, but zero crossings are commonly used. Whatever method you use, the time between changes of state will always affect the error rate. "Jitter," or random time variations, make it more difficult to decode the data accurately.

If a signal is corrupted by noise, both the levels and the zero crossing times will be affected.

Even when the signal is not noisy, phase distortion or delay will alter the zero crossing times. This also causes errors in the data. This effect is caused by differences in the time delays of the different frequency components of the signal as they pass through filters, like the IF filters in the radio. This also is known as "Envelope Group Delay," or "Group Delay Time."

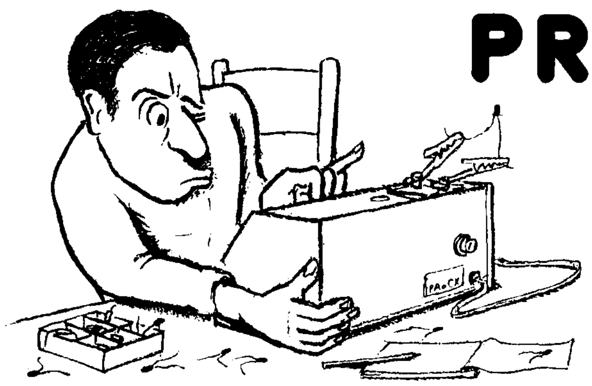
Conclusions

1. To send digital data at high speed over radio links, you must pay attention to signal quality (noise, distortion, and phase shift) in the communications channel.



2. A rule of thumb for FM is that the signal deviation should be about half the data bit rate. Another way to state this is: "The bandwidth is about equal to the data rate," since the channel bandwidth is twice the deviation.
3. The digital data must not have strong DC components. Either "bit stuffing" or a "shift register scrambler" should be used to prevent long strings of zero or one bits.
4. The receiver bandwidth should be reasonably matched to the signal bandwidth for best signal-to-noise ratio and lowest error rate.

Article H **HAM RADIO**



PRACTICALLY SPEAKING

Joe Carr, K4IPV

Antenna system instruments

One of the perennial topics addressed by Amateur Radio articles is the instrumentation needed for antenna systems. This isn't because there's nothing else to write about, but because readers continually request information about things like impedance bridges, noise bridges, and dip oscillators. This month I'll take a look at some of the basic instruments you might want to consider owning.

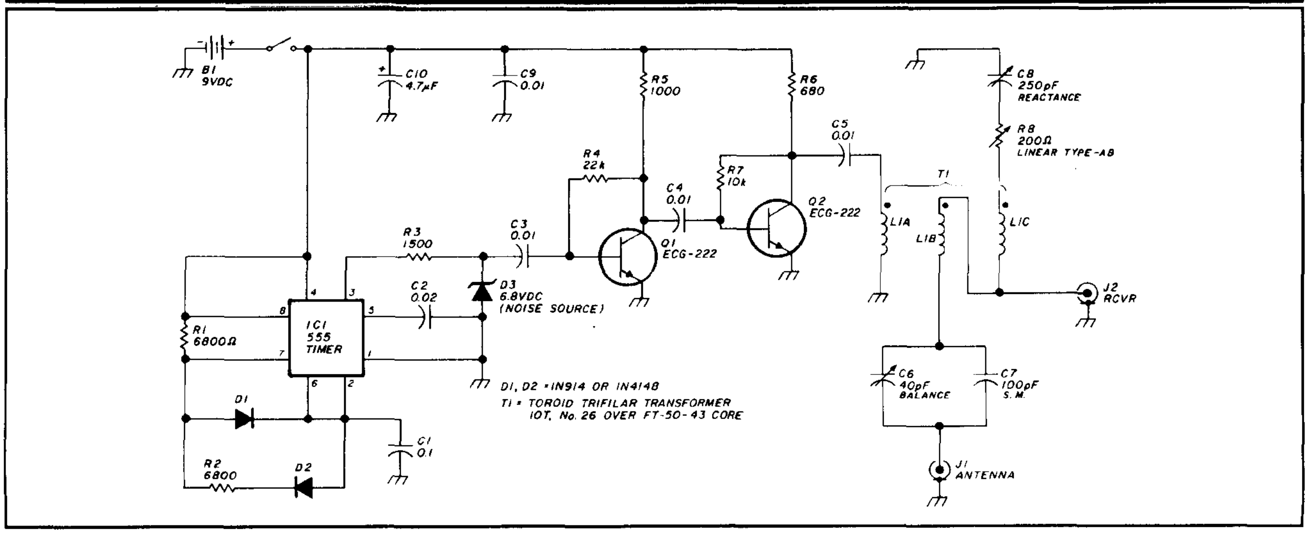
There are two main things to worry about when designing and installing Amateur Radio antenna systems. First, you need to know the frequency on which the antenna is resonant (hopefully, inside an Amateur band). Second, you need to know the feedpoint impedance, to make impedance matching easier (or, for that matter, possible). Let's take a look at some impedance bridges: *noise* types, VSWR bridges, and dip oscillators. There are more sophisticated instruments available, but these few are all most of us need for our antenna testing requirements.

The RF noise bridge

The RF noise bridge is a device that was once associated only with engineering laboratories, but it has Amateur Radio applications as well. Amateurs have been using noise bridges for many years, although at one time most of them were homebrew. The noise bridge is one of the most useful, low-cost, and often overlooked test instruments available.

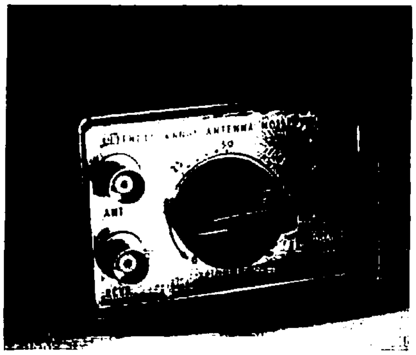
Several companies have produced low-cost noise bridges: Omega-T, Palomar Engineers, and most recently, the Heath Company. The Omega-T and the Palomar Engineers models are shown in **photos A** and **B**. The Omega-T device (**photo A**) is a small cube with one dial and a pair of BNC coax connectors (ANTENNA and RECEIVER). The dial is calibrated in ohms and measures the resistive component of impedance only. The Palomar Engineers device does everything the Omega-T does. It also lets you make a rough measurement of the reactive component of impedance. The Heath Company added their Model HD-1422 to the line-up; it's a "one-evening" kit. I reviewed the HD-1422 in my May 1986 column, so I won't elaborate on it here.

FIGURE 1



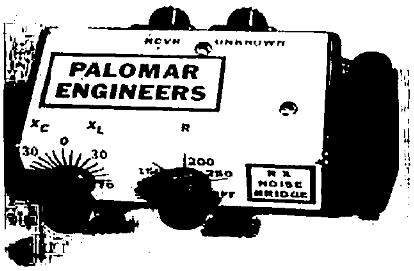
Noise bridge circuit.

PHOTO A



Omega-T noise bridge.

PHOTO B



Palomar Engineers noise bridge.

Over the years, some people have found the noise bridge useful for a variety of test and measurement applications — especially in the HF and low VHF regions. Its applications are not limited to antenna testing (the main job of the noise bridge). The two-way technician or Amateur Radio operator may use the device to measure antennas, tuned circuits, and resonant cavities.

Figure 1 shows a noise bridge circuit. The bridge consists of four arms. The inductive arms, L1b and L1c, form a trifilar-wound transformer over a ferrite core with L1a, so a signal applied to L1a is injected into the bridge circuit. The measurement consists of a series circuit made up of a 200-ohm potentiometer (R8) and a 250-pF variable capacitor (C8). The potentiometer sets the range (0-200 ohms) of the resistive component of measured impedance, while the capacitor sets the reactance component. Don't use a wire-wound potentiometer for R8. Capcitors C6/C7, in the unknown arm of the bridge, balance the measurement capacitor and should have a total value equal to one-half C8 (or about 125 pF). The bridge is balanced when C8 is in the center of its range and R8 is set to the resistance connected across J2, with C6/C7 in the circuit. This arrangement accommodates both inductive and capacitive reactances, which appear on either side of the "zero" point — the midrange capacitance of C8. When the bridge is in balance, the settings of R and C reveal the impedance across the unknown terminal.

A reverse-biased zener diode (zeners normally operate in the reverse-bias mode) produces a large amount of noise because of the avalanche process inherent in zener operation. While this noise is a problem in many other applications, it is highly desirable in a noise bridge; the richer the noise spectrum, the better the performance. The spectrum is enhanced because of the 1-kHz square-wave modulator that chops the noise signal. An amplifier boosts the noise signal to the level needed in the bridge circuit.

The detector used in the noise bridge is a tunable receiver which covers the frequencies of interest. The preferred receiver uses an AM demodulator, but both CW and SSB receivers will do in a pinch. The type of receiver you need depends on how precise an operating frequency is required for the device under test.

Adjusting antennas

Finding the impedance and resonant points of an HF antenna is perhaps the most common use for the antenna noise bridge. Connect the RECEIVER terminal of the bridge to the ANTENNA input of the HF receiver with a short length of coaxial cable. This length should be as short as possible, and the characteristic impedance should match that of the antenna feedline. Now, connect the coaxial feedline from the antenna to the ANTENNA terminals on the bridge. You're now ready to test the antenna.

Finding impedance. Set the noise bridge resistance control to the antenna feedline impedance (usually 50 or 75 ohms for most common antennas). Set the reactance control to midrange (zero). Next, tune the receiver to the antenna's *expected* resonant frequency (F_{exp}). Turn the noise bridge on, and look for a noise signal of about S9 (will vary on different receivers).

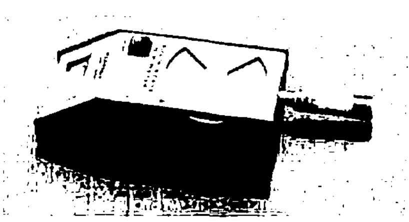
Adjust the *resistance* control (R) on the bridge for a null; i.e., minimum noise as indicated by the S-meter. Next, adjust the *reactance* control (C) for a null. Continue adjusting the R and C controls for the deepest possible null, as indicated by the lowest noise output on the S-meter (there is some interaction between the two controls).

A perfectly resonant antenna will have a reactance reading of zero ohms, and a resistance of 50 to 75 ohms. Real antennas may have some reactance (the less the better), and a resistance that is somewhat different from 50 or 75 ohms. You can use impedance-matching methods to transform the actual resistive component to the 50 or 75-ohm characteristic impedance of the transmission line. Here are the results you can expect:

1. If the resistance is close to zero, suspect that there's a short circuit on the transmission line; suspect an open circuit if the resistance is close to 200 ohms.
2. A reactance reading on the X_L side of zero indicates that the antenna is too long, while a reading on the X_C side of zero indicates the antenna is too short.

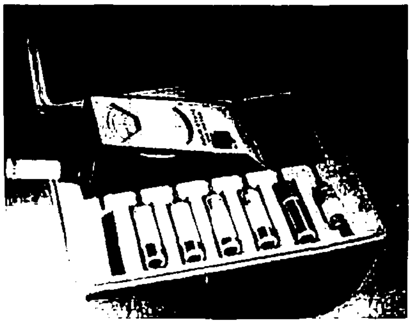
Adjust an antenna that's too long or too short to the correct length. To determine the correct length, you must find the actual resonant frequency, F_r. To do this, reset the *reactance* control to zero and then **slowly** tune the receiver in the proper direction — downband if it's too long and upband if it's too short — until you find the null. On a high-Q antenna the null is easy to miss if you tune too fast. Don't be surprised if that null is out of band by quite a bit. Find the percentage of change by dividing the expected resonant frequency (F_{exp}) by the actual resonant frequency (F_r), and multiply-

PHOTO C



Heath dip oscillator ready for use.

PHOTO D



Heath dip oscillator in case.

ing by 100: Change = (F_{exp} × 100 percent)/F_r).

Resonant frequency. Connect the antenna, noise bridge, and receiver as you did before. Set the receiver to the expected resonant frequency — approximately 468/F for half-wavelength types and 234/F for quarter-wavelength types. Set the resistance control to 50 or 75 ohms, as appropriate for the normal antenna impedance and the transmission line impedance. Set the reactance control to zero. Turn the bridge on and listen for the noise signal.

Slowly rock the reactance control back and forth to find on which side of zero the null appears. Once you've determined the null's direction, set the reactance control to zero and tune the receiver towards the null (downband if the null is on the X_L side and upband if on the X_C side of zero).

A less than ideal antenna won't have exactly 50 or 75-ohm impedance, so you'll have to do some adjustment of R and C to find the deepest null. You'll be surprised how far off some dipoles and other forms of antennas can be if they aren't in "free space;" i.e., they're close to the ground.

Dip oscillators

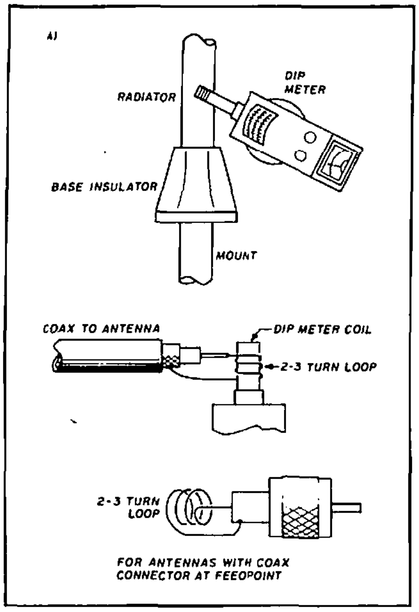
One of the most common instruments for determining the resonant frequency of an antenna is a "dip oscillator," or "dip meter" (see **photo C** and **D**). This instrument was originally called the "grid dip meter." The meter works because its output energy can be absorbed by a nearby resonant circuit, or antenna (which electrically is a resonant LC tank circuit). When the inductor of the dip oscillator is brought into close proximity with a resonant tank circuit, and the oscillator is operating on the resonant frequency, a small amount of energy is transferred. This energy loss appears on the meter pointer as an extremely sharp dip; you can miss it if you tune the meter frequency dial too rapidly.

Antennas are resonant circuits and can be treated in a manner similar to LC tank circuits. **Figure 2A** shows one way to couple the dip oscillator to a vertical antenna radiator. Bring the inductor of the dipper into close proximity with the base of the radiator. **Figure 2B** illustrates the way to couple dip oscillators to systems where the radiator is not easily accessible (as when the antenna is still erected). Connect a small 2 or 3-turn loop to the transmitter end of the transmission line, and then bring the inductor of the dipper close to it. A better way to do this is to connect the loop directly to the antenna feedpoint.

There are two problems to be aware of when using dip meters. As I said before, the dip is very sharp — it's easy to tune past it and miss it. To make matters worse, it's normal for the meter reading to drop off gradually from one end of the tuning range to the other. But if you tune very slowly, you'll notice a very sharp dip when you reach the resonant point.

The second problem concerns the dial calibration. The dial gradations of inexpensive dip meters are too close together and often erroneous. You'll be better off if you monitor the output of the dip oscillator on a receiver, and depend upon the receiver calibration for data.

FIGURE 2

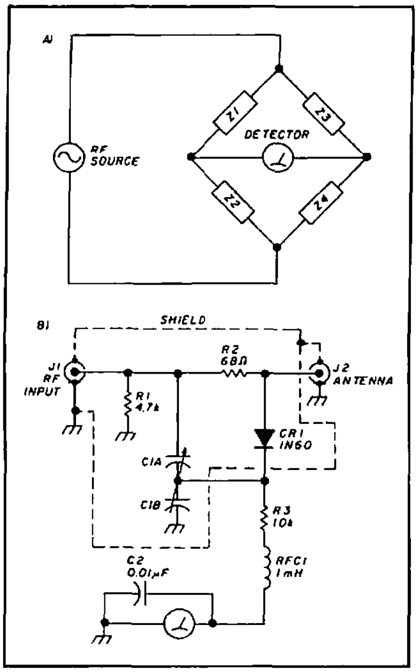


Coupling the dip oscillator to antennas. (A) directly, (B) indirectly.

Impedance bridges

It's important to know the antenna feedpoint impedance when designing and developing tactics for impedance-matching networks. Although it's best to measure the impedance exactly at the feedpoint of the antenna, it's very difficult to do. It isn't possible to measure the impedance on the ground and then expect it to be the same "at altitude" after you've erected the antenna. But there's hope for good measurements. Remember your basic transmission line theory? The load impedance value is reflected every half wavelength down the line. In other words, if you make the transmission line exactly an integer multiple of a half wavelength, the impedance measured at the input end will be the load impedance at the other end. The length of the line (in feet) should be $[(492 \times N \times V)/F_{MHz}]$, where N is an integer (1, 2, 3,...), V is the velocity factor of the transmission line used, and F_{MHz} is the frequency in megahertz. Although there's error involved because some coaxial transmission lines don't exhibit precisely the advertised velocity factor, the error is small enough to be ignored in most cases.

FIGURE 3



(A) Universal bridge circuit, (B) Amateur impedance bridge project.

Figure 3A shows the basic form of a simple impedance bridge. There are four arms, each representing an impedance. In general, two will be fixed, one will be variable and connected to a calibrated dial, and one will be the antenna. Another common arrangement is to have one fixed, two in the same "stack" (e.g., Z1/Z2) that are differentially variable, and the other as the antenna impedance. The bridge is in null (detector reads zero) when $[Z1/Z2] = [Z3/Z4]$.

Figure 3B shows an impedance bridge construction project you can build. The heart of this instrument is C1A/B, which is a 200 or 250-pF *differential* capacitor. The exact value isn't critical, but the range is affected. You can purchase these capacitors from Radiokit in Pelham, New Hampshire.* In order to read impedance values you'll need to supply a calibrated dial for the capacitor.

The value of resistor R2 is ideally 50 or 75 ohms. Select it to match the impedance of the antenna being measured. Selecting 68-ohm, 2-watt, carbon composition for R2 is a reasonable compromise. If you build this project, be sure to shield the RF components from the DC ones. The entire project is built in a shielded box, but the RF components should be shielded separately from the others.

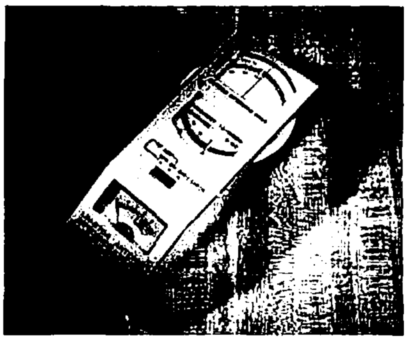
Calibration is simple. Select a handful of carbon composition resistors with values ranging from about 1 to 300 ohms. These are connected across J2, each in its turn. Make sure to represent 50 and 75 ohms in your collection so that you can find exact points on the dial. Find the null for each resistor using a low-power source, and mark its spot on the dial. Now calibrate the dial for the values you've selected.

The Leader Electronics commercial impedance bridge model shown in **photo E** is intended for Amateur applications. It contains an internal amplifier so that it can be used with ordinary signal generators, or in the "straight through" mode for use with low-power Amateur Radio transmitters.

VSWR bridges

Voltage Standing Wave Ratio (VSWR) indicates how well an antenna is matched to its source. **Photo F** shows a *simple, low-cost* bridge that will measure forward and reflected "relative" power. Although there's a calibration setting on the sensitivity potentiometer for measuring the output power of low-power transmitters, it's not too accurate for measuring RF power. However, it is good as a VSWR meter. One meter measures the forward power, while the

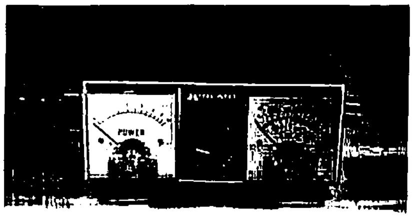
PHOTO E



Commercial impedance bridge.

*P.O. Box 973, 03076

PHOTO F



Two-indicator VSWR bridge.

other measures the reverse power. Once again, it's relative power that's being measured. Using the calibration knob, set the forward meter to exactly full scale with RF power applied. You can then read the VSWR from the reverse meter. In a future column I'll deal with the construction of various RF wattmeters and VSWR meters.

Conclusion

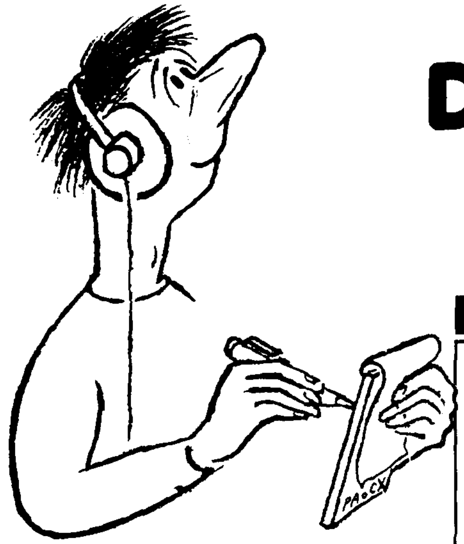
Antenna instruments are generally inexpensive, especially when compared with the cost of some antennas and transceivers on the market today. Some Amateurs feel they don't need to own such instruments. Yet they are so useful in "doping out" antenna systems, both when designing new installations and troubleshooting existing ones, that you'll find one handy. If you don't believe you need antenna instruments, then I've got a bridge up in K2-land to sell you.

Special note

The toroids column was suggested to me by a reader who must be a very special guy. Next time you buy a bottle of wine that bears the Bully Hill label, remember it's made by Walter Taylor, K2MLT. Because of legal problems with the Taylor Wine people, he can't use his own name — so call him Walter ________________. The artwork labels are a treat! Thanks, Walter.

You can reach me at POB 1099, Falls Church, Virginia 22041. I'd like to have your comments and suggestions for this column.

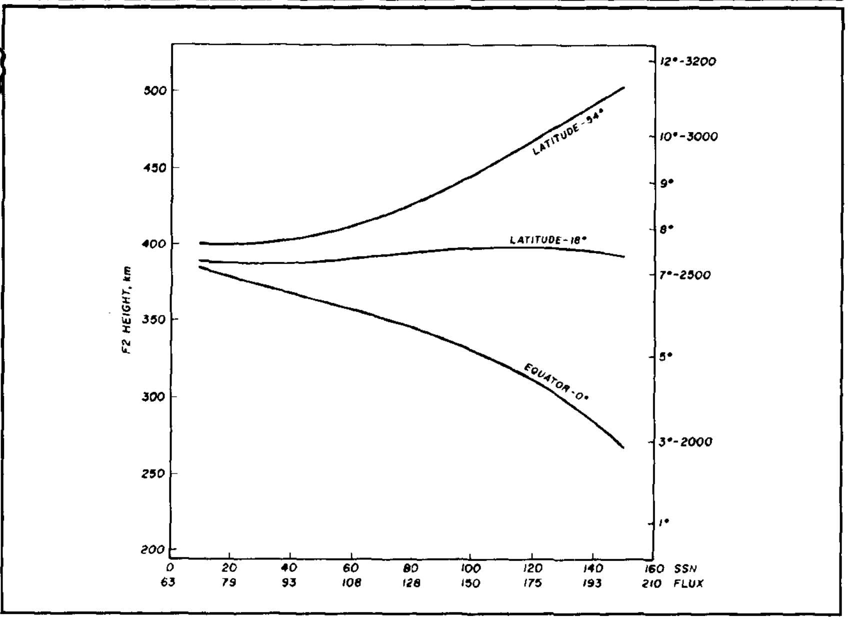
Article I **HAM RADIO**



DX FORECASTER

Garth Stonehocker, KØRYW

FIGURE 1



Cycle 22's increasing sunspot numbers and their effect on the F2 layer's average height.

More new cycle 22 DX

The new sunspot cycle nears its maximum by the end of 1989, causing some changes in signal propagation. The lower ionosphere (D & E) regions will increase by 30 percent, but the F region changes are more involved. Up there the geomagnetic field defines and controls the electron-ion density and altitude changes. Ion density will be generally increased, but the amount will vary with location. **Figure 1** shows the changes in height, both up and down. See the left ordinate scale at the latitude regions.

The height of refraction in the ionosphere determines the geometrical conditions of the maximum distance for DX. The earth tangent points spread out as the height increases. The figure's right-hand ordinate scale shows this change in hop length at a 10 degree take-off angle. If you have a favorite DX spot, the distance is fixed. For the signal to get to this same spot, the take-off angle will have to change as the height of the ionosphere moves. The angle change is also shown on the **fig. 1** right-hand ordinate scale for 3000-km distance.

Figure 1 is based on theory and geometry backed up by some research measurements. The solar flux and sunspot numbers change daily, and so do the relationships shown in **fig. 1**. On the average, the graph gives a good idea of what to expect by the end of 1989 or so. The hop distance, long skip, should increase by about 400 km on the northern paths to Europe or Japan while decreasing to countries in South America, South Africa, and the South Pacific.

Last-minute forecast

The best days for long-skip openings on the higher frequency bands are the first 12 days of February. Openings of one-long-hop transequatorial skip are probable near the 3rd and 10th to South Africa, South America, and South Pacific areas. Maximum usable frequencies (MUF) are expected to be highest because of high solar flux on these days. The lower bands are expected to be their best during the last two weeks. Disturbed periods from solar flare effects may be evident near the 3rd, 10th, and 21st with unsettled conditions. As a result of these effects, you can hear decreases in MUF with weak and variable QSB signals on east-west DX paths to Europe and Japan on the lower bands. Shorter nighttime hours will also be evident.

No significant meteor showers are scheduled to appear in February. A full moon occurs on the 25th; its perigee is on the 13th.

Band-by-band summary

Ten, 12, 15, 17, and 20 meters will be open from morning to early evening almost daily to most areas of the world. Expect the higher band openings to be southerly, shorter, and closer to local noon. Transequatorial propagation on these bands is likely to be toward evening during times of high

FEBRUARY

WESTERN USA

GMT	PST	N (Asia Far East)	NE (Europe)	E (S. Africa)	SE (S. America)	S (Antarctica)	SW (New Zealand)	W (Oceania Australia)	NW (Japan)
0000	4:00	20	30	15	10	10	10	10	12
0100	5:00	20	30	15	10	10	10	10	12
0200	6:00	20	*30*	20	12	10	10	10	15
0300	7:00	20	*30*	20	12	10	10	10	15
0400	8:00	30*	*30*	20	15	12	12	12	20
0500	9:00	30	*30*	20	15	12	12	12	30
0600	10:00	30	*30*	20	*15*	12	15	15	30
0700	11:00	30	*30*	*20*	*20*	12	15	15	30
0800	12:00	30	30	*20*	*20*	15	15	20	30
0900	1:00	30	*30*	*20*	*20*	*15*	20	20	30
1000	2:00	30	*30*	*20*	*20*	*20*	*20*	*20*	30
1100	3:00	*30*	*30*	*20*	*20*	*20*	*20*	*20*	30
1200	4:00	*30*	*30*	*20*	*20*	*20*	*20*	*20*	30
1300	5:00	*30*	20	12	15	*30*	*20*	*20*	*30*
1400	6:00	*30*	20	12	12	*20*	*20*	*20*	*30*
1500	7:00	30	15	10	12	15	*20*	*20*	*30*
1600	8:00	30	15	10	12	15	*20*	20	*30*
1700	9:00	30	15	10	10	12	15	20	*30*
1800	10:00	30	20	10	10	12	15	*20*	*30*
1900	11:00	*30*	20	10	10	10	12	15	*30*
2000	12:00	*30*	30	10	10	10	12	12	20
2100	1:00	*30*	30	12	10	10	12	12	15
2200	2:00	*30*	30	12	10	10	10	12	15
2300	3:00	*30*	30	15	10	10	10	10	12

MID USA

GMT	MST	N (Asia Far East)	NE (Europe)	E (S. Africa)	SE (S. America)	S (Antarctica)	SW (New Zealand)	W (Oceania Australia)	NW (Japan)	CST
0000	5:00	20	30	15	10	10	10	10	12	6:00
0100	6:00	20	30	20	12	10	10	10	15	7:00
0200	7:00	30	30	20	12	12	10	10	15	8:00
0300	8:00	30	*30*	20	15	12	12	12	20	9:00
0400	9:00	30	*30*	20	15	12	12	12	30	10:00
0500	10:00	30	*30*	*20*	15	15	15	15	30	11:00
0600	11:00	30	*30*	*20*	*15*	15	15	15	30	12:00
0700	12:00	30	*30*	*20*	*20*	*15*	15	20	30	1:00
0800	1:00	30	*30*	*20*	*20*	*20*	20	20	30	2:00
0900	2:00	*30*	*30*	*20*	*20*	*20*	*20*	*20*	30	3:00
1000	3:00	*30*	*30*	*20*	*20*	*20*	*20*	*20*	30	4:00
1100	4:00	*30*	20	15	*20*	*20*	*20*	*20*	30	5:00
1200	5:00	*30*	20	12	*20*	*20*	*20*	*20*	*30*	6:00
1300	6:00	20	20	12	15	15	*20*	*20*	*30*	7:00
1400	7:00	20	15	10	15	15	*20*	*20*	*30*	8:00
1500	8:00	30	15	10	12	15	*20*	*20*	*30*	9:00
1600	9:00	30	15	10	10	15	15	15	*30*	10:00
1700	10:00	30	20	10	10	12	15	20	*30*	11:00
1800	11:00	30	20	10	10	12	12	15	*30*	12:00
1900	12:00	30	20	10	10	12	12	15	30	1:00
2000	1:00	*30*	30	10	10	10	12	12	20	2:00
2100	2:00	*30*	30	12	10	10	12	10	15	3:00
2200	3:00	*30*	30	12	10	10	10	10	15	4:00
2300	4:00	*30*	30	15	10	10	10	10	12	5:00

EASTERN USA

GMT	EST	N (Asia Far East)	NE (Europe)	E (S. Africa)	SE (Caribbean S. America)	S (Antarctica)	SW (New Zealand)	W (Oceania Australia)	NW (Japan)
0000	7:00	*30*	30	15	12	12	12	10	20
0100	8:00	30	30	20	12	12	15	12	30
0200	9:00	30	30	20	15	12	15	15	30
0300	10:00	30	*30*	20	15	15	20	15	30
0400	11:00	30	*30*	*20*	15	15	20	20	30
0500	12:00	30	*30*	*20*	*15*	15	20	20	30
0600	1:00	30	*40*	*20*	*20*	*20*	20	*20*	30
0700	2:00	*30*	*40*	*20*	*20*	*20*	*20*	*20*	30
0800	3:00	*30*	*40*	*20*	*20*	*20*	*20*	*20*	*30*
0900	4:00	*30*	*40*	*20*	*20*	*20*	*20*	*20*	*30*
1000	5:00	*30*	20	12	*20*	*20*	*20*	*20*	*30*
1100	6:00	20	20	10	15	*20*	*20*	*20*	*30*
1200	7:00	20	20	10	15	15	*20*	*20*	30
1300	8:00	20	15	10	12	15	20	15	30
1400	9:00	30	15*	10	12	15	20	15	30
1500	10:00	30	15	10	10	15	20	15	30
1600	11:00	30	15	10	10	12	*20*	20	30
1700	12:00	30	15	10	10	12	15	20	*30*
1800	1:00	30	20	10	10	12	15	20	*30*
1900	2:00	30	20	10	10	12	12	15	*30*
2000	3:00	*30*	20	10	10	10	12	12	20
2100	4:00	*30*	30	12	10	10	12	10	15
2200	5:00	*30*	30	12	10	10	10	10	15
2300	6:00	*30*	30	15	10	10	10	10	12

The italicized numbers signify the bands to try during the transition and early morning hours, while the standard type provides MUF during "normal" hours.

*Look at next higher band for possible openings.

solar flux and disturbed geomagnetic field conditions.

Thirty and 40 meters will be useful almost 24 hours a day. Daytime conditions will resemble those on 20 meters, but skip and signal strength may decrease during midday on days with high solar flux values. Look for good nighttime use — except predawn after days of very high MUF conditions. Usable distances on these bands should be somewhat greater than that achieved on 80 at night.

Eighty and 160 meters, the nighttime DXer's bands, will open just before sunset and last until sunrise on the path of interest. Except for daytime short-skip signal strengths, high solar flux values have little effect. Geomagnetic disturbances, more evident at the equinoctial periods, cause signal attenuation and fading on polar paths. Noise increases noticeably on these lower frequency bands in the coming months. Please remember the DX windows.

Article J **HAM RADIO**

THE WEEKENDER

A transmit timer for the KPC-2

One of life's most embarrassing moments is finding your packet TNC has glitched and tied up a busy packet channel for several hours. My TNC, an older Kantronics KPC-2, doesn't have a transmitter time-out timer. Several circuits have been published as solutions to this problem, but I feel mine is a novel approach because it uses existing circuitry to incorporate a timer. You add only two diodes, a resistor, and a single capacitor.

The KPC-2 is a fine TNC, but as with many devices with internal microprocessors, erratic supply voltage fluctuations can cause the internal program to "crash" and the TNC to go into continuous transmit mode. Besides the embarrassment, you also run the risk of burning out your transmitter PA.

Before you start

All of the modifications are performed on the KPC-2 pc board. You should have some expertise doing minor pc board modifications before attempting this one. I also advise you to use a *grounded soldering station* and take the necessary precautions against static discharge. Your Kantronics warranty and factory service options may be adversely affected by this installation.

Opening the TNC

Remove the pc board through the front of the case. The bezel and front panel are held in place by two screws. Before you can slide out the board, you *must* remove the screw mounting the 7805 to the case.

By Peter J. Bertini, K1ZJH, 20 Patsun Road, Somers, Connecticut 06071

Attempting to slide the board forward before removing this screw will damage the regulator. Avoid disturbing the LED indicators or they won't mate with the panel cutouts during reassembly.

Timer length

Most packet operations require transmit times of 10 seconds or less. For file transfers, transmit times of 20 seconds or more are common. Some packet conference systems use TX times of up to a minute. Using a 100-k resistor value for R1 yields a 10-second time limit; a value of 560 k for R1 allows 60 seconds before time-out.

Preparing the board

Using your KPC manual pictorial layout, locate IC U14. This a 74HC04 14-pin device. Locate pin 13 and carefully cut the trace to the pin on the solder side of the board. *Verify that you have the correct pin before cutting the run!*

Now install diode D2 and resistor R1 between pin 13 and Vcc (5-volt bus). Pin 14 of U14 is the Vcc supply for the chip. I elected to mount the diode on the solder side of the board, and tacked the resistor directly to the IC pins topside. *Observe diode polarity* — the cathode (bar) must go to pin 14!

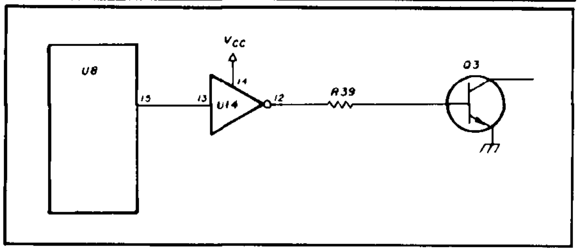
Locate the solder pads for U13. This device is not used on the KPC-2. On the component side of the board you'll find two or three pads for U13 that are connected to the ground bus. Select one of these pads and carefully cut it free of the ground connection. Next prepare diode D1 and capacitor C1. You'll mount these components between pin 13 of U14 and the open pad on U13. Cut the leads to length and put spaghetti over the exposed leads before soldering. Again, note the polarity. The positive lead of C1 and the cathode (bar) of D1 must go to pin 13 of U14. There will be three leads connected to pin 13 of the IC at this point, so solder carefully! Now, trace the cut run from pin 13 of U14. You'll find it goes to one of two solder-through connections in the vicinity of U8. Solder a short piece of wire-wrap wire from this point back to the freed pad of U13, where capacitor C1 and diode D1 were terminated.

This completes the modification. Carefully recheck your work to be sure everything is right before you put the KPC-2 back together. Note that my pc board is version PC 35. Your KPC may use a different revision level, and have a different parts layout than mine.

Checking it out

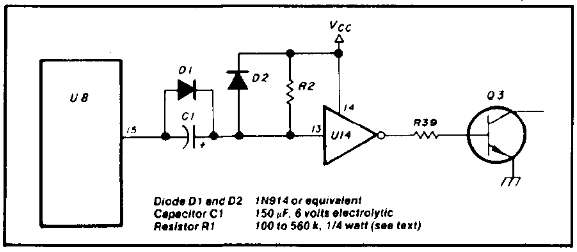
Put your station back together and select a quiet packet frequency. Monitor your transmissions on another receiver. Select the calibrate mode for the TNC; refer to the manual if you're not familiar with this command mode. Your terminal will give you an R, T, or X prompt. Hitting the T key should key your transmitter. You'll hear a calibration tone on the monitor receiver if

FIGURE 1



Partial schematic of unmodified TNC.

FIGURE 2



Addition of timer components to TNC circuitry.

everything's working correctly. Hitting the R key should immediately drop the transmitter. Toggle back and forth between the R and T keys several times to confirm that the TNC is keying and unkeying the radio properly. Now select the T key and wait — the TNC should time out eventually. After time-out, immediately hit the R and T keys again. The transmitter should come back on until you hit the R key, or until the next time-out. The X prompt is supposed to terminate the calibration mode, but you'll find that you have to turn the TNC off and back on to resume normal operation.

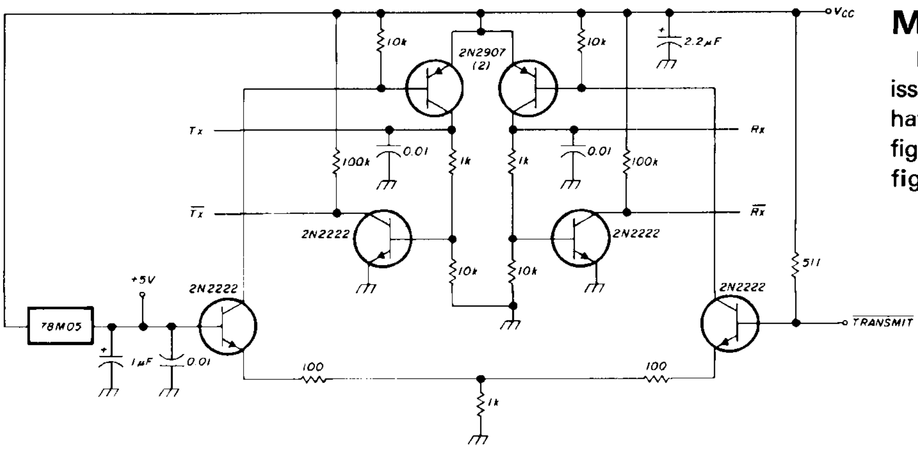
Theory of operation

Look at **figs. 1** and **2**. Normal TX keying is started by a low-going signal from the microprocessor on pin 15. This signal is inverted to a high-going one by way of an inverter section in U14. The high-going signal drives Q3 into conduction through current-limiting resistor R39. The open-collector output of Q3 provides the ground-return keying for the transceiver.

In the modified circuit, capacitor C1 is normally discharged. During transmit, the negative lead of C1 is brought low. The charging current for C1 maintains a low state on pin 13 of U14, until C1 reaches a charge voltage equal to the threshold of pin 13 on U14. The value of R1, in conjunction with the source current provided by the inverter input, and the value of C1 determine the actual time interval before time-out. D1 forces an immediate high level to the inverter when going to receive. Diode D2 provides a discharge path for C1 during the receive state; this prevents consecutive packet exchanges from causing a cumulative time-out. I suspect this circuit might be adaptable to other TNCs, although I haven't investigated that possibility. Purists may wish to include a small resistor, under 100 ohms, in series with C1 to limit the inrush current on pin 15 of the microprocessor.

Article K **HAM RADIO**

short circuit



Missing figure

Please note that in the October 1988 issue, **fig. 7** shown on page 26, should have been included in **fig. 9**. The figure shown here should have been **fig. 7** in Part Three of N6GN's article.

FLEA MARKET

RATES Noncommercial ads *10¢ per word*; commercial ads 60¢ per word **both payable in advance**. No cash discounts or agency commissions allowed.

HAMFESTS Sponsored by non-profit organizations receive one free Flea Market ad (subject to our editing) on a space available basis only. Repeat insertions of hamfest ads pay the non-commercial rate.

COPY No special layout or arrangements available. Material should be typewritten or clearly printed (**not** all capitals) and must include full name and address. We reserve the right to reject unsuitable copy. **Ham Radio** cannot check each advertiser and thus cannot be held responsible for claims made. Liability for correctness of material limited to corrected ad in next available issue.

DEADLINE 15th of second preceding month.

SEND MATERIAL TO: Flea Market, Ham Radio, Greenville, N. H. 03048.

BEGINNER'S RADIO CLEARINGHOUSE. On a space available basis, we are going to offer you, OUR SUBSCRIBER, free of charge, a chance to find a home for your used equipment with a new Ham. Please send us a short description of what you want to sell along with price, name, address and phone number. We'll *run it once* in a special section of the classified ads under the heading of BEGINNER'S RADIO CLEARINGHOUSE. Please limit your ad to 20 words or less.

GOOD BEGINNER RIG. Heath SB-101 transceiver with HP-23 supply, SB-600 speaker, CW filter, extra tubes, manual $250. Contact WA7GVT (406) 365-2261.

NATIONAL Radio Manual and NCL-2000 factory parts lists. SASE. Max Fuchs, 11 Plymouth Lane, Swampscott, MA 01907.

ELECTRONIC KITS & ASSEMBLIES. For our latest catalog send SASE (45 cents) to: A & A ENGINEERING, 2521 W. LaPalma, #K, Anaheim, CA 92801.

IBM-PC SOFTWARE FOR PK-232. New CompRtty II/PK is the complete communications program for the PK-232/HK-232. Uses host mode of PK-232 for complete control. Text entry via built-in screen editor! Adjustable split screen display, including optional Triple Split (TM) in Packet mode. Instant mode/speed change. Hardcopy, diskcopy, break-in buffer, select calling, text file transfer, customizable full screen logging, 24 programmable 1000 character messages, mailbox facility. Ideal for MARS and traffic handling. Requires 256k PC compatible. $65. Non-PK-232 version still available. Send call letters (including MARS) with order. David A. Rice, KC2HO, 144 N. Putt Corners Rd, New Paltz, NY 12561.

GROUND RADIAL WIRE for verticals or slopers. Improves performance, new #16 bare *solid* copper. LOWEST COST, 1000 foot spool, $38 includes shipping. DAVIS RF, PO Box 230-H, Carlisle, MA 01741. (508) 369-1738.

COMMODORE/AMIGA chips, (eg. 6510–$11.55, 6526–$12.50, 6567–$19.95, 6581–$13.85, PLA/82S100–$14.75, 901 ROM series–$11.50), parts, diagnostics, hard to find items. Authorized service center. Fast repairs, low cost (eg. C64-$49.49 plus UPS). Heavy duty power supplies for the C64-$28.00 plus UPS. KASARA MICROSYSTEMS, (Division of QEP), Rt. 9W/Kay Fries Drive, Stony Point, NY 10980. 1-800-248-2983 (outside NY) or 914-942-2252.

COMPUTER CODE COURSE: Apple II +/c/e/GS. C-64/128. 37 modes, graphics, 1-100 WPM, menus, proportional spacing, variable frequency, more ($29.95). With word processor ($39.95). Manual ($10). Check/MO. LARESCO, POB 2081-HR, Calumet City, IL 60409. 1-312-891-3279.

UHF PARTS. GaAs Fets, mmics, chip caps, feedthrus, teflon pcb, high Q trimmers. Moonbounce quality preamps. Electronic sequencer boards. Send SASE for complete list or call (313) 753-4581 evenings. MICROWAVE COMPONENTS, PO Box 1697, Taylor, MI 48180.

KITS*PARTS*PLANS. We have hard to find parts! Variable tuning capacitors, tuning coils, crystal and magnetic headphones, germanium diodes, crystal, shortwave and tube type kits. Very inexpensive. Send 25 cent stamp for catalog. Yeary Communications, 12922 Harbor #800HR, Garden Grove, CA 92640.

$50 PACKET Digicom 64—software based PACKET system for Commodore 64. Software is public domain and requires a modem for the C64 which is provided by our kit. Board plugs directly into cassette port or remote mounted via cable, both connectors included. Watchdog rimer, reed relay PTT and PTT inversion options included. Power derived from computer. Uses 7910 chip—no alignment required. Switch allows HF or VHF operation. Order Kit #154 for $49.95 or Assembly #154 for $79.95 both include FREE DISK. Add $2.50 s/h. A & A ENGINEERING, 2521 W. LaPalma #K, Anaheim, CA 92801. (714) 952-2114. MC or VISA accepted.

DIGITAL AUTOMATIC DISPLAYS. Any Radio. Be specific. GRAND SYSTEMS, POB 2171, Blaine, WA 98230.

QUALITY HAM SOFTWARE for the IBM-PC and compatibles. Many shareware and public domain disks for all aspects of ham radio. Business SASE for catalog. JK&S Dept HE, PO Box 50521, Indianapolis, IN 46250-0521.

MAGAZINES WANTED: "Microwave Systems News" (MSN), "RF Design", "PCIM (Power Conversion & Intelligent Motion)" and "QEX" (1980-present). Call collect 519-742-4594 (Ontario) after 6 PM Eastern time.

IMRA International Mission Radio Association helps missionaries. Equipment loaned. Weekday net, 14.280 MHz, 1-3 PM Eastern. Nine hundred Amateurs in 40 countries. Rev. Thomas Sable, S.J., University of Scranton, Scranton, PA 18510.

MACINTOSH Ham Software. MacTrak(tm) tracks satellites, sun, moon. Graphic or tabular outputs. Compatible with Mirage Tracking Interface for rotor control, $59.95. **DX Helper™** provides DX info including distance, bearing, sunrise, sunset, propagation MUF, great circle display, more, $34.95. SASE for info from R. Stegemeyer, PO Box 1590, Port Orchard, WA 98366.

BACK ISSUES OF HAM RADIO. Have most issues from 1969 to 1974. Mint condition. $3.00 for single issues. WN0G, 319-377-3563.

MICROWAVE GENERATORS: All checked, working: HP-626A, HP-628A, HP-8690A sweep gen, $150/ea. FXR L772A 1-2 GHz, $75. GR-1218A 1-2 GHz, GR-1021A VHF/Gen 40-250 MHz, $100/ea. GR-1601A VHF bridge $125. Also test equipment: HP-410C meter w/out probe, $100. GR-1611A capacitance bridge $100. GR-650A *impedance bridge*, $55. All $75: Tektronix 190B generator; C-27 camera; type-82; type-M plug-in units; Measurements 188 FM/Gen; Sorensen QSB28-8 DCPS, 10-40V, 8Amps, Var/Reg, metered; Alfred HVPS .2-3.5KV. 23mA, Var/Reg, metered; Heath EU-205 2-Pen Chart Recorder Hi-Sens w/access; GR-1672A Digital System Control; Theta Resolver Test Set; Military SRR-11 VLF receiver 14-600 kHz. ALL $35: GR-1604A; Krohn-Hite 330A Var/Lab Bandpass Filter; HP-412A DC-VOM; HP-130C; HP-416A Ratiometer; Ballantine 3600 DVM w/TRMS. Also H-V Plate Transformers, 4400V/CT 235mA; 3500V/CT 275mA, $75/ea. Giant Powerstat 220V/28A, 0-280V, 7.8KVA $145. SASE list. Joseph Cohen, 200 Woodside, Winthrop, MA 02152. 617/846-6312.

ANTENNA PARTS AND CATALOG. Lowest costs. Dipole/Quad/Ground Radial Wire, insulators, center feeds, open wire feed line, coax, relays, (#14 multistrand dipole/quad wire, non-stretch, very flexible, $34 per 275' (minimum), $.12/ft. thereafter, includes shipping. Catalog $2.00. DAVIS RF, PO Box 230-H, Carlisle, MA 01741. (508) 369-1738.

HAM TRADER YELLOW SHEETS. In our 27th year. Buy, swap, sell ham radio gear. Published twice a month. Ads quickly circulate—no long wait for results. Send No. 10 SASE for sample copy. $13 for one year (24 issues). PO Box 2057, Glen Ellyn, IL 60138-2057 or PO Box 15142, Dept HR, Sattle, WA 98115.

VHF-UHF-SHF. Large SASE. West Coast VHFer, POB 685, Holbrook, AZ 86025.

CHASSIS & CABINET KITS. SASE. K3IWK, 5120 Harmony Grove Rd. Dover, PA 17315.

ANALOG AND RF CONSULTING for the San Francisco Bay area. Commercial and military circuits and systems. James Long, Ph.D., N6YB (408) 733-8329.

RTTY JOURNAL—Now in our 36th year. Read about RTTY, AMTOR, PACKET, MSO'S, RTTY CONTESTING, RTTY DX and much more. Year's subscription to RTTY JOURNAL $10.00, foreign slightly higher. Order from: RTTY JOURNAL, 9085 La Casita Ave., Fountain Valley, CA 92708.

WANTED: Hammarlund HQ170AC vhf, and HQ180AC, prefer Mint Cond. Mike Matich, PO Box 515, Cedar Ridge, CA 95924. (916) 477-0622.

RUBBER STAMPS: 3 lines $5.00 PPD. Send check or MO to G.L. Pierce, 5521 Birkdale Way, San Diego, CA 92117. SASE brings information.

CASH OR TRADE for all types of transmitting or special purpose tubes. M & S COMMUNICATIONS ENGINEERING 160 So. Auburn Street, Suite 200, Grass Valley, CA 95945. (916) 272-5500.

ELECTRON TUBES: Receiving, transmitting, microwave... all types available. Large stock. Next day delivery, most cases. DAILY ELECTRONICS, PO Box 5029, Compton, CA 90224. (213) 774-1255.

MOTOROLA MAXAR 80. 800 MHz 2-way w/mike/PL. Good condition $250. Heathkit 20 SSB mobile $125. Hallicrafter SX101A $125. Bob Shuman, 725 S. Chocolay, Clawson, MI 48017.

EXPLORE the license free 160-190 kHz band. Communications over 100 miles have been achieved and our kits will help you get on the air fast! Send stamp for brochure to: SEDEN COMMUNICATIONS, 1272 Harold Avenue, Simi Valley, CA 93065

WANTED: ARC-5 and SCR-274 equipment, parts and accessories, any condition. Ken, WB9OZR, 362 Echo Valley, Kinnelon, NJ 07405. (201) 492-9319.

WANTED: Ham equipment and other property. The Radio Club of Junior High School 22 NYC, Inc. is a nonprofit organization, granted 501(C) (3) status by the IRS, incorporated with the goal of using the theme of Ham Radio to further and enhance the education of young people. Your property donation or financial support would be greatly appreciated and acknowledged with a receipt for your tax deductible contribution. We sponsor the classroom net on 7.238 at 1200 UTC daily and encourage your QSL for our weekly award. Please write us at: PO box 1052, New York, NY 10002 or call our round the clock hotline: (516) 674-4072. Thank you!

CLEANING OUT LIBRARY. Send SASE for big list of ham radio and electronic books and magazines (HR, CQ, 73, QST, Wireless World, Popular Electronics, etc). Joe Holstein, N8EA, 1515 Sashabaw, Ortonville, MI 48462.

CUSTOM MADE EMBROIDERED PATCHES. Any size, shape, colors. Five patch minimum. Free sample, prices and ordering information. HEIN SPECIALTIES, Inc., Dept 301, 4202 N. Drake, Chicago, IL 60618.

RECONDITIONED TEST EQUIPMENT $1.25 for catalog. Walter, 2697 Nickel, San Pablo, CA 94806.

SCHOLARSHIP. The Dayton Amateur Radio Association is now accepting applications for its 1989 Scholarship Program. The program is open to any licensed Amateur graduating from high school in 1989. For information and application forms write Scholarship Committee, 317 Ernst Avenue, Dayton, OH 45405.

COMING EVENTS

Activities — "Places to go . . ."

SPECIAL REQUEST TO ALL AMATEUR RADIO PUBLICITY COORDINATORS: PLEASE INDICATE IN YOUR ANNOUNCEMENTS WHETHER OR NOT YOUR HAMFEST LOCATION, CLASSES, EXAMS, MEETINGS, FLEA MARKETS, ETC, ARE WHEELCHAIR ACCESSIBLE. THIS INFORMATION WOULD BE GREATLY APPRECIATED BY OUR BROTHER/SISTER HAMS WITH LIMITED PHYSICAL ABILITY.

KENTUCKY: February 11. Ham Radio & Computer Fest, Cave City Convention Center, Cave City. Setup 6 AM. Doors open 8 AM. Admission $3/advance. DX, Packet, Antennas forums. VE exams. Activities for the entire family. Talk in on 145.410 or 146.52.

MICHIGAN: The Cherryland ARC's 16th annual Swap-N-Shop, East Bay Elementary School, 3962 Three Mile Road N., Traverse City. 8 AM to 2 PM. Admission $3.00. Tables $6.00. Talk in on 146.850 repeater. For information Mike Hubbard, N8JXY, 5772 Vance Road, Interlochen, MI 49643. (616) 276-9143.

OHIO: February 12. The Mansfield Mid-Winter Hamfest/Computer Show, Richland County Fairgrounds, Mansfield. Doors open 7 AM. Tickets $3/advance; $4/door. Tables $6/advance; $8/door. For additonal information, tickets or tables SASE to Dean Wrasse, KB8MG, 1094 Beal Road, Mansfield, Ohio 44905 (419) 589-2415 after 4 PM EST.

COLORADO: February 19. The Aurora Repeater Association's 8th annual Swapfest, Jefferson County Fairgrounds, 15200 W. 6th Avenue, Golden. 8 AM to 3 PM. For information contact Judi, WD0HNP (303) 460-1413 or Jan, KA7TYU, PO Box 39666, Denver, CO 80239.

MINNESOTA: February 25. Midwinter Madness Hamfest, Medina Ballroom, Median. 7 AM to 2 PM. Admission $3/advance; $5/door. For information contact Dennis Pollard, KZ01. (612) 535-7189 evenings.

FLORIDA: February 25. The 7th annual Hernando County Hamfest, Hernando County Fairgrounds Auditorium, US 41 South (4 miles south of Brooksville). Doors open 8 AM. Advance registration $2.00; at the door $3.00. Swap tables $8.00. Free parking. Overnight parking permitted. No facilities. For advance registration SASE to Hamfest Chairman, PO Box 1721, Brooksville, FL 34605.

SOUTH CAROLINA: February 25. The Charleston Amateur Radio Society's annual Hamfest, National Guard Armory, 89 Hagood Avenue, Charleston. For information E.L. Sikes, N4LS, 16 Trumbo Street, Charlston, SC 29401 or call (803) 723-4000.

TEXAS: February 25. The Orange ARC's 4th annual Hamfest-Flea Market, National Guard Armory Buildong, Meeks Drive, Orange. 9 AM to 5 PM. Setup time 7 AM. Tables $4.00. Dealers $10. Talk in on 147.180.

GEORGIA: February 25. The Dalton ARC's annual Hamfest, North Georgia Fairgrounds. For information write DARCI, POB 143, Dalton, GA 30722-0143. Or contact members via GA cracker net or GA SSB net.

OHIO: February 25 and 26. ARRL Ohio section convention, Cincinnati Gardens Exhibition Center, Langdon Farm Road and Seymour Avenue, Cincinnati. 8:30 to 5 both days. For information contact Stan Cohen, WD8QDQ, 2301 Royal Oaks Ct, Cincinnati, Ohio 45237 (513) 531-1011.

INDIANA: February 26. The LaPorte ARC's Hamfest, LaPorte Civic Auditorium. Admission $3.50. Reserved tables $3. Talk in on 146.520 or 146.610 with PL of 131.8. Contact SASE LPARC, PO Box 30, LaPorte, IN 46350.

OHIO: February 26. The Cuyahoga Falls ARC's 35th annual Hamfest, Akron North High School. 8 AM to 3 PM. Tickets $3/advance; $4/door. Reserved tables $5. Or bring your own. For information Bill Sovinsky, K8JSL, 2305—24th Street, Cuyahoga Falls, OH 44223. (216) 923-3830.

VIRGINIA: February 26. Vienna Wireless Society's Winterfest. Vienna Community Center, 120 Cherry Street, Vienna. Setup 6 AM. General public 7:30 AM. Admission $4/door; $7/tailgate. Talk in on K4HTA/R 146.085/146.685 or W4LBL/R 146.190/146.790. For information Harry Kaklikian, W4ACN, 4941 Andrea Avenue, Annandale, VA 22003.

MICHIGAN: February 26. The 19th annual Livonia ARC's Swap 'n Shop, Dearborn Civic Center, Dearborn. 8 AM to 4 PM. ARRL/VEC exams. Free parking. Talk in on LARC Repeater 144.75/5.35 and 146.52. For information SASE to Neil Coffin, WA8GWL, Livonia ARC, POB 2111, Livonia, MI 48151.

KENTUCKY: March 4. The 13th annual Glasgow Swapfest, Cave City Convention Center, Cave City. Sponsored by the Mammoth Cave ARC. 8 AM to ??? Admission $3. Tables $3. Flea market, VE exams. Talk in on 146.34/94. For additional information N4HCO, 1379 Whites Chapel Road, Glasgow, KY 42141.

TEXAS: March 4 and 5. South Texas Amateur Repeater Society Hamfest, Casa de Amistad (Civic Center) on Fair Park Blvd, Harlingen. Saturday 9-4. Sunday 9-2. Flea market, VE exams RACES/ARES meeting, ARRL forum and more. Talk in on 147.99/.39 English, 146.10/.70 Spanish. Admission $5/advance; $6/door. Tables $7/advance; $10/door. For information K5RAV, 2210 S. 77 Sunshine, Harlingen, TX 78550. (512) 425-7744.

PENNSYLVANIA: March 5. The 2nd annual York Springfest (Ham & Computer), Dover Firehall, York. Free tailgating, indoor tables $10. Registration $4. Unlicensed spouse and under 12 free. VE exams. General admission 8 AM. talk in on 146.37/97 and 147.93/33. *For information and registration* (301) 239-3878 or write YORK Springfest, PO Box 50, Shrewsbury, PA 17361-0050.

PENNSYLVANIA: March 5. The Two Rivers ARC's Hamfest, Rostraver Fire Hall, PA 51, McKeesport. 8 AM to 3 PM. Admission $1.00 at door. Full table $6. Half table $4.00. Talk in on 146.13/73, WA3PBD/R Repeater. For information Louis H. Zimmerman, N3GPJ, 911 Roland Road, Wilkins Twp, PA 15221. (412) 351-1562 10 AM to 10 PM.

MASSACHUSETTS: March 5. Mt. Tom Amateur Repeater Association Amateur Radio and Electronics Flea Market, Smith Vocational School, Rt 9, Northampton. Setup 7 AM. Doors open 9 AM to 2 PM. Admission $2. Under 12 free accompanied by adult. Tables $10/advance; $12/door. VEC walkin exams. Talk in on 146.94, 223.82 and simplex 146.52. Handicapped parking and access. Reservations: Bob, WB1EQS (413) 532-6411 days. Mickey, N1CDR (413) 562-1027 evenings. Or write MTARA Flea Market, 6 Laurel Ter, Westfield, MA 01085.

NEW JERSEY: March 12. The Delaware Valley Radio Association's 17th annual HAMCOMP '89, New Jersey National Guard 112th Field Artillery Armory, Eggerts Crossing Road, Lawrence Township. 8 AM to 2 PM. Admission $3/advance; $4/door. Indoor spaces $7 and $10. Outdoors $6. Sellers bring own tables. Setup 6 AM. Public 8 AM. Talk in on 146.07-.67. For information and space reservations write HAMCOMP '89, c/o KB2ZY, RD 1, Box 259, Stockton, NJ 08559. Please SASE. Handicap parking and wheelchair accessible.

INDIANA: March 12. The Morgan County Repeater Association's Indiana Hamfest, Indiana State Fairgrounds Pavilion Building, Indianapolis. Starts 8 AM. Admission $5. 8' tables $8. Free parking. VE exams. Talk in on 145.25. For information or table reservations SASE before 2/24/89 to Aileen Scales, KC9YA, 3142 Market Place, Bloomington, IN 47403. (813) 339-4446.

FLORIDA: March 18 and 19. The Playground ARC's 19th annual North Florida Ham/Swapfest, Shrine Fairgrounds, North Ft. Walton beach. Doors open 8 AM both days. Admission $3/advance; $4/door. Tables $10 one day or $15 for both days. Flea market, exhibits, ARRL, MARS and OCWA meetings. Saturday night banquet. Free parking. RV parking $10 with hookup. Talk in on 146.79 and 52. For information write PARC, PO Box 873, Ft. Walton Beach, FL 32548.

ILLINOIS: March 19. The Sterling-Rock Falls ARS 29th annual Hamfest, Sterling High School Field House, 1608 Fourth Avenue, Sterling. Doors open 7:30 AM. Tickets $3/advance; $4/door. Dealers, large flea market, VE exams. Talk in on 146.25/146.85 W9MEP Repeater. for information, tables or tickets contact Sue Peters, PO Box 521, Sterling, IL 61081 or call AC (815) 625-9262.

NEW JERSEY: April 15. "Flemington Hamfest 89", sponsored by the Cherryville Repeater Association, 8 AM in the Hunterdon Central High School Field House. Admission: $4 advance, $5 door. Children under 12 and XYLs free. Refreshments available from 6:30 AM. Advance tickets: Dave Hickson, KD2RC, 125 South Main St, Lambertville, NJ 08530. Tables: Marty Grozinski, NS2K, 6 Kirkbridge Rd, Flemington, NJ 08822. Information: (201) 788-4080 before 11 PM EST. VE testing begins at 10 AM, send FCC form 610, photocopy of current license, and a check for $4.75 (payable ARRL/VEC) to: Cherryville Repeater Association, VE Test Team, Box 308, Quakertown, NJ 08868. Talk in: 146.52, 147.975/375, 145.615/015, 222.52/224.12 and 449.85/444.85 MHz.

DAYTON HAMVENTION: April 28, 29, 30.

OPERATING EVENTS

"Things to do . . ."

AMATEUR RADIO DAY. *February 25. Hams will call all nations* from Official Center of the World. A special event station, WA6BEZ, will be set up for one day and manned by licensed volunteers from the Yuma Amateur Radio Emergency Service. For more information contact, KC0KV, Yuma ARES.

AMATEUR RADIO CLASSES: For those people interested in obtaining a Novice (basic level) Ham license or upgrading to Tech/General, the Chelsea Civil Defense, in cooperation with QRA Radio Club, will sponsor Amateur Radio Communications classes evenings at Chelsea High School starting MARCH 7, 1989. For more information write Frank Masucci, K1BPN, 136 Grove Street, Chelsea, MA 02150. Please enclose your telephone number.

THE MIT UHF REPEATER ASSOCIATION and the MIT Radio Society offer monthly HAM EXAMS. All classes Novice to Extra. Wednesday, February 15, 7 PM, MIT Room 1-150, 77 Mass Avenue, Cambridge, MA. Reservations requested 2 days in advance. Contact Ron Hoffmann at (617) 484-2098. Exam fee $4.50. Bring a copy of your current license (if any), two forms of picture ID, and a completed form 610 available from the FCC in Quincy, MA (617) 770-4023.

product REVIEW

N6RJ's Computerized Second Op v1.01

Those of you who go back a few years will remember W9IOP's *manual* Second Op. This handy operating aid was updated by *HR* and N6RJ in the early 80's to reflect the latest postal rates, callsign assignments, and other helpful information.

N6RJ and KL7GRF have taken the next logical step by integrating the power of the MS-DOS computer with the Second Op. Their new computerized version has just been made available.

This new program isn't a rehash of the old Second Op. It surpasses the older version and offers almost every feature you could want in a data base type program. Here's what you get:

Logging and scanning of log capabilities, oblast, QSL bureaus, bearing-sunrise-sunset, and add and edit notes on countries. Print functions include a DXCC country list with distance, bearing, DXCC "need" list, Oblast worked/confirmed, Oblast log, and many other different log printing capabilities. In summary mode you can show: DXCC worked/confirmed on all bands, one band, one band and one mode, by mode, detailed spreadsheet worked/confirmed for each band, and mode with mixed totals; WAZ by band, mode or both, and 6-band WAZ summary; and total station entries in log. In the log print mode you can print your DXCC need list (by mode or mixed), or your entire log in almost any format imaginable. The Second Op supports most printers and includes laser printer drivers.

One of the most maddening aspects of operating is keeping an up-to-date country list handy for all the different prefixes in use. This is where the Second Op really shines. Ask the computer to find a country by prefix and you have the information you need in a flash (see fig. 1). Have only an old prefix and want to cross it to the new ones? Second Op can do that tool

Oblast hunters will find that the new Second Op is a great addition to their shack. (Working Oblasts on 160 is difficult so I don't have much experience here.) After reviewing this function, I found that I understood more about Oblasts than I ever did before. You can find Oblasts by entering either callsign or Oblast number. You can also keep a running record of worked and confirmed Oblasts.

The owner's manual is one of the best I have ever seen. It clearly documents each and every feature, and gives full and complete installation instructions. Novice computer users may be interested to know that KL7GRF is available to help with any problems running the Second Op. I must admit that, as MS-DOS is still an enigma to me, I had problems getting the program to work properly myself. A quick phone call to GRF brought plenty of helpful hints and a full explanation of what I had done wrong. Within minutes I was able to correct my mistakes and get the program to run flawlessly.

This value-packed program is a welcome addition to the ham shack. All hams, from contesters and honor roll DX'ers to casual operators, will find that the new Second Op adds greatly to their computing capabilities. I'm sure that W9IOP would be proud to see what his Second Op has become and would have one in his shack.

The New Second Op is available from the **HAM RADIO** Bookstore for $59.95 plus $3.50 shipping and handling.

de **N1ACH**

FIGURE 1

```
N6RJ END OF 17:09 UTC

Prefix..........VU          DXCC Country..INDIA

CQ Zone.........22          Kilometers....[illegible]   Location...BOMBAY
Continent.......AS          Long Path.....[illegible]   Sunrise....00:59 UTC
Direct Bearing..[illegible] Return Path...[illegible]   Sunset.....13:11 UTC
Nautical Miles..[illegible] Latitude......[illegible] N 3rd Party..NO
Statute Miles...[illegible] Longitude.....[illegible] E Reciprocal.YES

Air Mail........0.45        N6RJ Notes...
Air QSL Card....0.36        Notes line 1.
IRC.............4           Notes line 2.
ARRL Bureau.....YES         Country......Worked:Y    Confirmed:Y

              [illegible] BY PREFIX

 F1  | F2  | F3    | F4    | F5  | F6      | F7     | F8  | F9   | F10
FIND | NEXT| [illegible] | ORDER | EDIT| BEARING | BUREAU | LOG | HELP | MENU
```

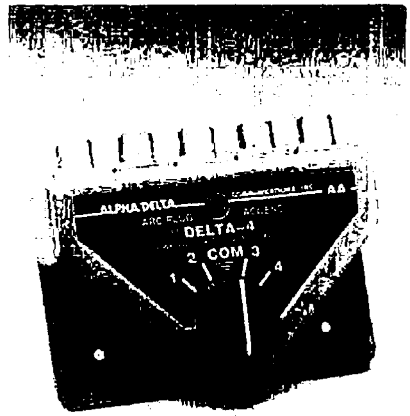
This is the print screen display of what you'd see when you enter VU (by prefix). For the larger countries additional bearing and sunrise/sunset information is available. When you hit the F6, or bearing key (displayed here), you'll see what's printed on the next page.

NEW products

New switch design

Alpha Delta's model Delta-4/4N switch incorporates several significant design improvements.

The new switch allows Easy Arc-Plug cartridge access through the front panel. The previous design required the removal of the back-plate.



Front panel access makes permanent switch mounting possible. The pill can be removed with a magnetized screwdriver blade, after you unscrew the hex retainer. The Delta-4 also has a redesigned roller bearing drive for a smoother "feel" during rotation.

Because many people mount the switch on a desk top, all the connectors run along one side so that the coax cables can run back behind the desk.

Models are available with UHF (SO-239) or type "N" connectors.

For more information contact Alpha Delta Communications, P.O. Box 571, Centerville, Ohio 45459.

Circle #301 on Reader Service Card.

1.2-GHz handheld transceiver

ICOM has introduced the new 1.2-GHz IC-12GAT handheld transceiver. It features: wideband coverage, one-watt power output,

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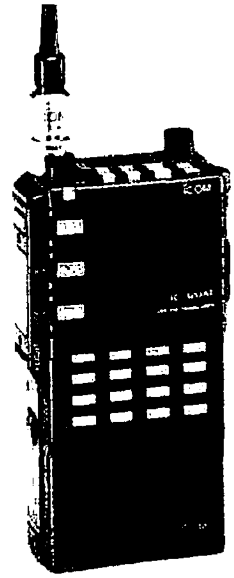

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ELMER's NOTEBOOK

Tom McMullen, W1SL

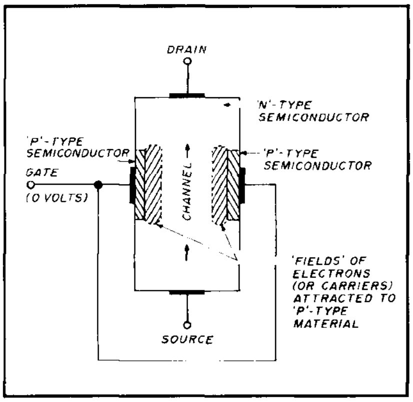
FETs—the other transistors

When I discussed bipolar transistors in last month's column, I made reference to Field-Effect Transistors (FETs). Let's look at a few ways that these transistors differ *from* their bipolar cousins in both construction and operation. Field-effect and bipolar transistors share a common chemistry — both use "N" or "P"-type semiconductor material. The type designations tell you whether there is a surplus of electrons (N type) or a scarcity of electrons (P type) in the basic make-up of the material. The transistors differ in their manner of operation and how the N or P material is made to control the flow of electrons.

Putting the pieces together

Let's use a FET that is constructed of N-type material to explore what happens inside. The body of the transistor is made of material having a surplus of electrons. This body, called a "channel," must have connections at each end for application of the external power source. One connection is made to the negative (−) terminal of a supply or battery and one to the positive (+) terminal. In FET terminology, one of these connections is a *"source," and the other is a "drain."* It makes sense when you consider that the source is where the electrons come from and the drain is where they go (see **fig. 1**). In order to control the current flow between the drain and source, you must add another element — a "gate." The gate is another terminal connected to the body of the FET, but not in exactly the same way as the source and drain.

FIGURE 1



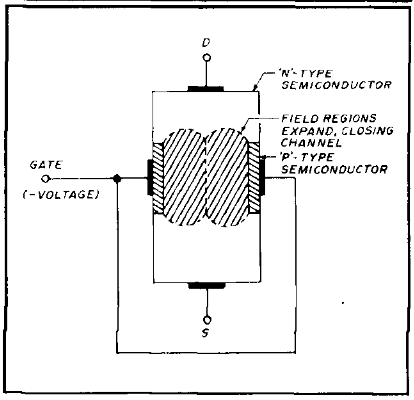
A simple FET has basically two parts: a channel for electron flow, and a gate to control that flow. The channel here is N-type material, and the gate is P-type. The shaded region near the gate area indicates "depletion" zones that affect the current flow in the channel. With zero volts on the gate, the zones are small, allowing current to flow.

The gate terminal is attached to P-type material that is deposited on the N-type channel. This P-type material has a scarcity of electrons, and the lack of electrons creates a "field" that extends into the channel material. Electrons (carriers) in the N-type channel are attracted to the gate material, *but are stopped from getting through* by a very thin barrier between the two. When the field caused by this attraction is small, and confined to an area near the gate, current can flow easily from source to drain. (Actually, that's a gross simplification of what happens. Theoretical purists talk about things like minority and majority carriers, valence bonds, enhancement and depletion modes. I prefer to keep it simple.) In the FET's normal resting state, full current flow takes place with the gate at zero volts. The shaded area in **fig. 1** shows the "field" at minimum, with the channel open for current flow.

Putting on the pinch

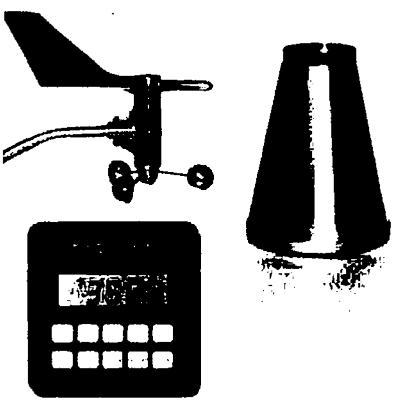
Things start to happen when a voltage is applied to the gate. If the voltage is positive, the field shrinks, opening the channel more than normal. If the voltage is negative, the field becomes larger. The enlarged field decreases the current flow between source and drain. If the field becomes large enough it blocks the flow completely, as shown in fig. **2**. This blocking of a path between the source and

FIGURE 2



When a voltage of the correct polarity is applied to the gate, the depletion zone expands, decreasing current flow. In this case, a negative (−) voltage has increased the depletion zone to the point where all current is stopped. This is called the "pinch-off" effect.

NEW products



The unit is portable and comes with wind vane, anemometer, weather computer unit, and 40 feet of control cable (extendable to 200 feet). The complete TWR-32 unit is $159.95 plus $4.95 shipping and handling. Foreign orders add $17.00 shipping. Get a special FREE bonus Azimuth Dual-Zone 24 hour Station/Travel Clock with 15 world-wide cities (a $29.95 value).

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The Bird Electronic Corporation Model 43 THRULINE® wattmeter is now available in a true peak power reading version. The 43P lets you measure true peak power of single sideband, AM modulated RF, and certain limited rectangular pulse signals to an 8 percent F.S. accuracy, without affecting CW measurement capabilities. It uses standard Bird plug-in elements. Depending on the element selected, the overall frequency range is 450 kHz to 2.3 GHz, and RF power is 100 mW to 10,000 watts.

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Owners of the standard Model 43 can modify their units with a retrofit kit, Model 4300-400, to obtain the same peak power measuring capability as the 43P. The kit includes a pc board which mounts inside the Model 43 housing.

For more information contact your Bird distributor, or the Bird Electronic Corporation, 30303 Aurora Road, Solon, Ohio 44139-2794.

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drain is called the "pinch-off" effect because it pinches off, or closes, the channel so that current can't flow.

Think of the channel as a rubber hose connected between a water faucet (the source) and your kitchen sink (the drain). If you squeeze the hose between your thumb and finger, you "pinch off" the flow of water. When you relax your thumb and finger, some water will flow. You control the flow by changing the pressure exerted by your fingers.

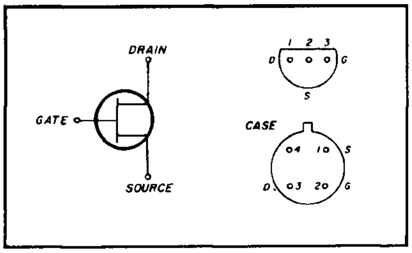
The FET works in much the same way. The depth of the field near the gate material can be altered to change the current flow by adjusting the voltage (voltage is the electrical equivalent of pressure). When more voltage is applied to the gate terminal, the pinch-off region gets larger, and less current flows through the channel.

These relatively simple FETs are sometimes called JFETs, for Junction Field-Effect Transistors. The gate and channel material and the junctions resemble a diode, and the "boundary" separating the N and P material is very thin. Once the gate voltage is high enough to overcome that boundary, the device acts just like a diode, and the field-effect performance is lost.

This limitation is overcome in some FETs by the introduction of a thin insulator between the gate and the channel material. The insulator prevents diode action and, at the same time, increases the input resistance of the gate tremendously. These devices are sometimes called IGFETs (Insulated Gate Field-Effect Transistors) or MOSFETs (Metal-Oxide Semiconductor Field-Effect Transistors). Still other varieties have more than one gate, and some contain exotic materials (like sapphire). These transistors are tailored to a specific industry need or purpose; we don't need to get into their physics and chemistry at this point.

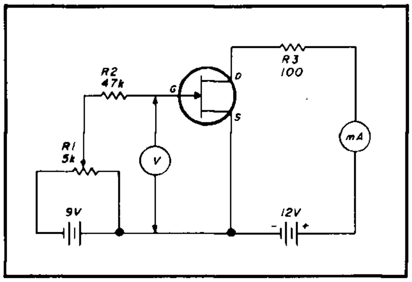
The schematic symbol for a FET is shown in **fig. 3**. The direction of the arrowhead on the gate connection indicates whether the device is an "N-channel" type or "P-channel" type. Some manufacturers place the arrowhead on the source lead instead of the gate. There are no easy "clues" for using the direction of the arrow to determine the type of device, but I have noticed that the majority of manufacturers have the arrow pointing in for N-channel FETs.

FIGURE 3



The schematic symbol for a FET, and two common base diagrams. The direction of the arrow on the gate connection tells whether the FET is an "enhancement" or "depletion" type, but is not as useful to us for identification as was the emitter symbol in bipolar transistors. Please note that there are many different base diagrams, so be sure to find the correct one before hooking up any device.

FIGURE 4



Schematic diagram of the hookup used in the experiment described in the text.

Checking the theory

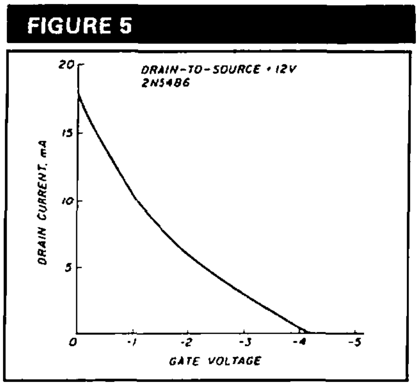
Now that I've discussed how FETs are supposed to work, it's time to get out the meters, batteries, resistors, etc., and see what really happens. First, look at a specifications sheet to see what you should expect. I have a plastic parts drawer full of miscellaneous FETs; one of them has a label I can still read — 2N5486. This is an RF-amplifier device, so a change in gate voltage should produce a somewhat linear response in the drain current (as opposed to a switching-type device where the change would be abrupt). The specifications sheet tells me that maximum voltage between drain and source is 25Vdc, the maximum drain current (I_D) is 30 mA, and that the device maximum dissipation is 310 mW, so I'll keep those limits in mind. One column on the sheet shows that the gate reverse current at 15 Vdc is 1 nA! That's 1×10^{-9} A (0.000,000,010 A). I don't have a meter that will measure such a small current, so I'll take their word for it! Figure 4 shows the setup used for measurement in this experiment.

Because a FET is supposed to be a voltage-operated device, the 47-k resistor (R2) connected to the gate should have no effect other than limiting current flow in case something shorts in the night. The 100-ohm drain resistor, R3, provides drain short-circuit protection. Gate voltage is adjusted by means of a 5-k potentiometer, R1.

If things work the way the numbers predict, the FET should show current flow as soon as I complete the circuit between source and drain, with no voltage on the gate. Sure enough, that's what happens. The meter shows 18 mA, which is within the range of 8-20 mA listed for this FET. The voltage from drain to source is 12, so the device is dissipating 0.216 watts, or 216 mW — comfortably below the 310-mW limit given in the spec sheets.

Theory says that if I place a negative (−) voltage on the gate, the channel should close, decreasing current flow. I decided to give it a try. At −0.5 volt on the gate, drain current started to drop. The reading was 14 mA. Increasing the gate voltage caused drain current to decrease even more, until at 4.5 volts the current was too small to measure with my simple milliammeter. The graph in **fig. 5** shows the results of measuring gate voltage versus drain current at several points along the way. Incidentally, a 0-50 μA meter placed in series with R2 showed only a tiny flicker of movement, indicating that little or no current was flowing in the gate circuit.

What about applying a positive voltage to the gate? After I reversed the 9-volt battery, a gate voltage of + 0.1



The measurements obtained in the setup of *fig. 4* are shown in this graph.

produced current flow of 19 mA; going to +2 volts increased drain current to 21 mA. Increasing the gate voltage to the full +9 volts produced no further increase in drain current. This indicates that the channel is wide open at approximately +2 volts on the gate, and passing all the electrons it can when the supply is 12 volts. Higher supply voltages will, of course, allow higher current to flow. If you replace the 100-ohm current-limiting resistor with a suitable load resistance (or transformer, RF choke, etc.), you can develop a respectable output voltage across the resistor in response to gate voltage changes. Thus, a small voltage change at the input can create a large voltage swing at the output, providing useful amplification.

There are other FETs that have the opposite characteristics. With these FETs, the channel is "pinched off" with zero voltage on the gate, and application of the proper polarity voltage opens the channel to current flow. You can best determine which device does what by looking at its specifications, but you can also hook up a few simple instruments and components to see for yourself.

Keep in mind that the components and meters that I've used are not precision devices, and the results may not agree exactly with those published by the manufacturers. They are, however, accurate enough for exploring the theory of operation in an inexpensive way.

The numbers I've come up with in both this experiment and that of last month's column on bipolar transistors measure only a small sample of the many transistors available. Some devices work at voltages and currents much smaller than I used; others, like power amplifiers, work with higher voltages and with currents of many amperes. The devices I've worked with here are linear — they provide a smooth change in output in response to a change in input. Others behave like switches — a change in input produces an abrupt change in output, which remains relatively constant until the input voltage is removed.

Some of the bargain packs or grab bags provide many interesting experiments at low cost, and you'll be hard pressed not to learn something from them! Why not join in the fun?

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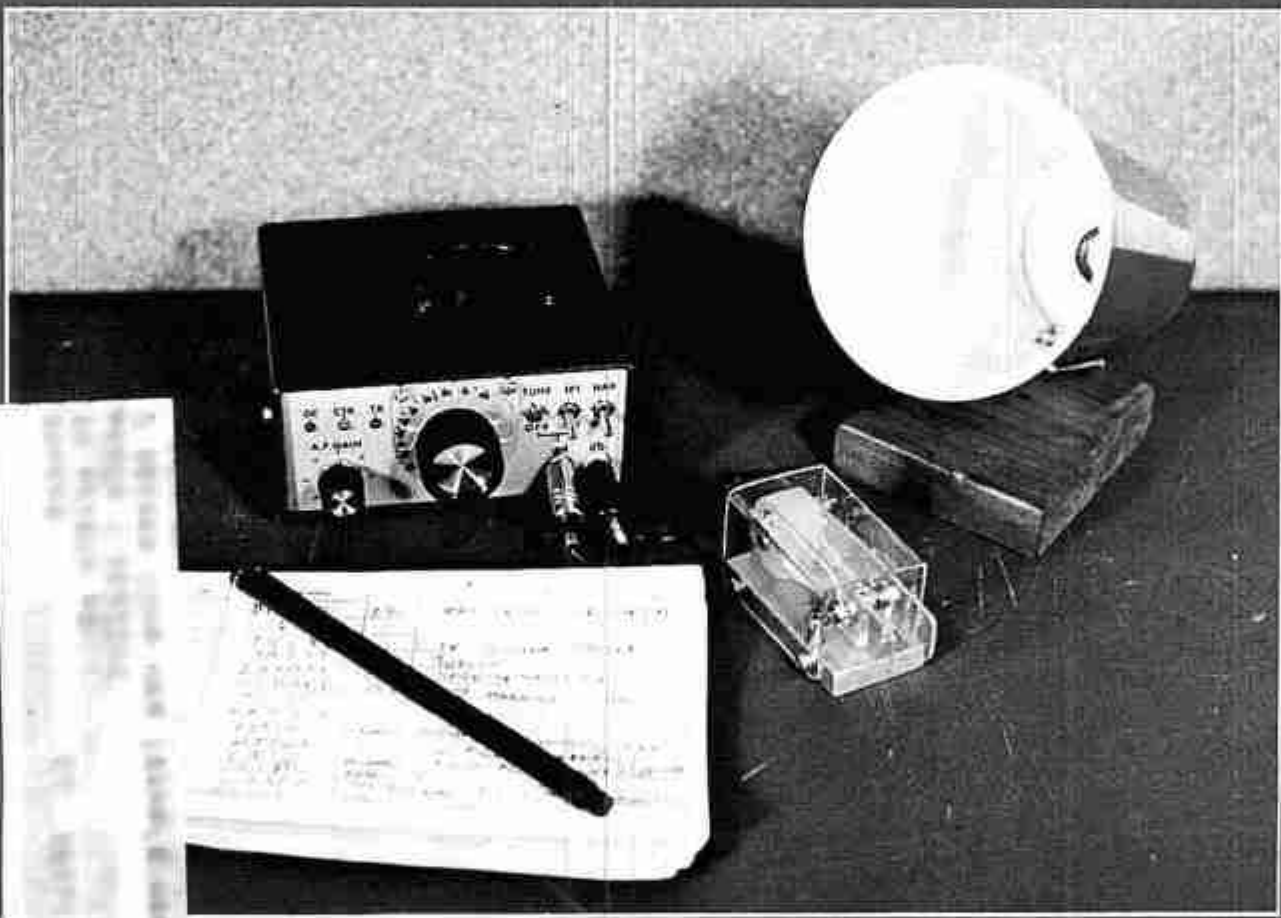

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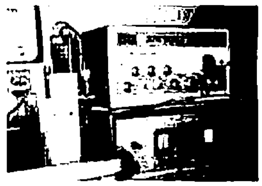


W3NNL, page 8

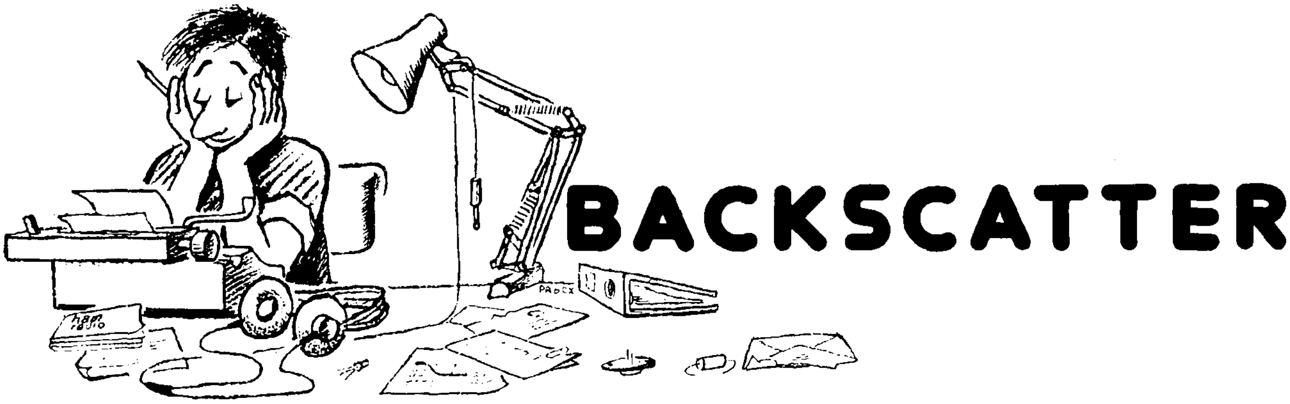
I4MK, page 59

KB1QT, page 12
AA4NX, page 53

On the Cover:
Solo-16 Acoustic CW Speaker.

See page 93 for the winners of January's Weekender contest.

DEPARTMENTS



NO-CODE REVISITED

The no-code license concept has resurfaced in the Amateur Radio press. In the December 1st issue of *W5YI REPORT*, Fred Maia, W5YI, reopened "Pandora's box" and suggested that a no-code license be considered once again. Citing the decreased number of youths interested in becoming hams, several other interrelated factors, and the political climate in Washington, Maia feels that now is the time to actively reconsider no-code.

A number of countries already have no-code VHF licenses; Canada is considering implementing one in the very near future. But what is no-code, *really*? *Is it an attempt to get thousands of new "hams"* into the hobby at the expense of those already licensed? Or is it a logical outgrowth of incentive licensing and a step that should have been taken over 20 years ago?

Obviously this is going to be an emotional, highly charged question. The January issue of *QST* has a rather well-balanced editorial discussing code and its applications to the Amateur Radio service. As a democratic organization, the ARRL members are the ones that will make ARRL policy about code. In the last no-code round, letters ran 25 to 1 against the proposal. *QST*'s January 1989 issue, continuing to echo that feeling, contains 13 pro-code letters. Early in January, the League set up a study committee to look at the subject of code. The members are: W4OYI, K1ZZ, and KB6ZV, representing the League; W2GD and KØPP (Montana's SCM) from the general Amateur community; N7ML and W5TOO from the Amateur Radio industry; VE3CDM, CRRL President; and W5KL, QCQA President. Hopefully, this group won't succumb to emotional interests and will take a balanced look at all the issues before making any recommendations to their fellow Amateurs. Arguments can be made for both sides of the controversy. However, does Amateur Radio need growth at this time, or is a 2 to 3 percent per year growth rate adequate? Some Amateurs feel that the bands are already crowded enough and that further growth will be counterproductive to Amateur Radio. Others argue that a basic qualifier, like code, serves as a filter to eliminate those who don't belong in the Amateur ranks. You could make an argument that code at 5 WPM is hardly an insurmountable barrier. I find it of interest that making the theory test easier than the one currently taken by Novices isn't even an issue. (I'd like to know if professionals in the education field think that learning the code is really an impediment to getting a ham license. Or are some people who don't want to put in the effort just looking for a convenient cop-out?)

But the League doesn't represent all licensed Radio Amateurs — in fact less than half of the Amateur population are League members. What about the rest of you; where do you stand?

The current licensing system is based on a series of rewards for diligence and study. It might make sense to give beginners two choices. The no-code license would have *limited* VHF (or UHF) frequencies and voice and data privileges. The other beginner's ticket would have all the current Novice HF bands, and the new class license privileges. By passing a Morse code test, the no-code beginner would be able to upgrade to HF privileges.

I'm certainly not proposing that we eliminate code from the Amateur Radio service entirely. There's no argument that code has been, and will continue to be, a most important mode of communication in Amateur Radio. But is there a continuing need in Amateur Radio for the hurdle of learning the code at the beginner's level? Several years ago, industry pundit Wayne Green petitioned the FCC to make code exams mandatory at license renewal time. The argument was that you've got to learn the code to get a license, so continuing to maintain proficiency is also important. The docket was rejected, but I'd bet you'd find many pro-code adherents scrambling to brush up on long-forgotten CW skills when it was time for them to renew.

It will be interesting to see what happens with the no-code situation over the next few years. I'm sure there will be ample give and take. Maia's proposal deserves study and thought. The emotional argument that "I had to do it — so do they" doesn't hold water with me.

What do you, the *Ham Radio* Magazine readers, think? Are you pro no-code or con? Send me a QSL card with your vote. We'll give you the results in a couple of months.

Craig Clark, N1ACH

COMMENTS

What's in the future for ham radio?

Dear HR

It's not that I'm the kind of fellow who's quick to say "I told you so"; I waited three whole hours!

Of course the ham bands are under siege. It has been obvious to me and to many other concerned hams that Uncle Sam and the communications industry have their eyes on the ham bands, and that they have every intention of obliterating ham radio. Let's face it, we have (as hams) outlived our usefulness.

See your own words referring to ham radio as "our hobby." See the number of publications promoting contests. See the total devastation of ham radio activities during contest periods (contesting is not a proper ham radio activity). See the "appliance operator" nature of the ads in your own magazine (Radio Shack's CB Extension Speaker). See the Dick Bash travesty. See ARRL's VOLMON substitute for FCC policing of the ham bands. See the volunteer examination ripoff.

Listen to the average, trivial "QSOs" and inane "QTCs" that pollute the bands in between contests.

About all hams do these days is provide emergency communications a few times a year, and much of that is so poorly handled.

So, why should "our hobby" fare any better than others' — like fishing, philately, etc.? We are occupying a lot of valuable space in the RF spectrum, but we surely don't deserve it.

See? I told you so.

A.J. (Buddy) Massa, W5VSR,
New Orleans, Louisiana 70174.

What do you think readers? Is Amateur Radio a 'hobby or a service? What's your opinion? Ed.

A candid opinion

Dear HR

I often wish "letters to the editor" columns in magazines would find something more interesting to print than praise from readers/subscribers. Unfortunately, *HR* is in this category as well.

I am not afraid to be told that my opinion is in the minority, but I will frankly express my opinion that the magazine which once included words to the effect that it was devoted to communications technology has now strayed considerably from that aim.

I just received the annual receiver issue which usually has been, for me, the most interesting one of the year. I think the November issue, in line with an apparent goal to print articles which can describe circuits that can be built simply or inexpensively, is the dullest I have yet seen.

Again, despite a possible majority of PRESENT subscriber interest in the new orientation, I think it's an almost CQ/73 clone now.

Considering the receiver issue, a Dr. Ulrich Rohde would seemingly not be at home with the new orientation.

It is quite correct that the cover no longer emphasizes "communications technology."

Simon L. Scheiner,
Cherry Hill, New Jersey 08034

On the other hand .....

Dear HR

I would like to add some comments about your new format.

I have worked in electronics for more than 22 years, 8 years in supervision, starting out in communications with a FCC license. I have always found your magazine interesting and am interested in projects. However, I find that for the beginner, like some youngster that has a Novice license or whomever, that some articles are very complex needing a knowledge of higher math. I'd like to see some articles on such math as that used in the magazine. I'd like to see articles that deal with projects for the ham station, articles on procedures and operation. In some ways ham radio has left our newer operatives behind. How about a series of articles on the step-by-step construction of a transceiver, including the math needed to design it? That is what ham radio was all about years ago. Some persons would like to experiment, but there is a limit on what they can afford to spend. How about some articles that deal with tuning transmitters to FCC specs, etc. — areas where there is little published information for the new operator.

Thank you for letting me express my views.

William C. Pollard,
Georgetown, Texas 78628

And ....

Dear HR

I surely did enjoy the November 1988 *Ham Radio* especially "Simple Receivers," by Bill Parrott.

I like the direction you are going by putting several projects and circuits in the magazine.

Keep up the good work, but be careful, you may inject some technology back into amateur radio. Hi.

Fenton Wood, KB5VQ, Malakoff, Texas 75148-9613

Memories of the China Clipper

Dear HR

Bill Orr's article, "Ham Radio Techniques," in the November 1988 issue brought back some memories. I lived

(continued on page 109)

THE HEATHKIT SENECA® AS A 2-METER FM AMPLIFIER

Increase your handheld's output power to 70 watts

There are two motives for using old "boat anchors" in modern-day ham radio: nostalgia and low cost. In many applications, the performance of this gear is so inferior to state-of-the-art equipment that its use is undesirable. But now and then you find a use which is both practical and consistent with realistic objectives.

Such was the case when I finally succumbed to the 2-meter bug. My change of heart was prompted by the decline in sunspots and the corresponding difficulty of maintaining communications with the local gang on the DC bands. I found a Heathkit Seneca for $15 at a hamfest and bought it with the idea of getting on 2-meter CW using a GLB converter for receiving.

The 6 and 2-meter Seneca (of early 1960s vintage) has a built-in VFO, which is too unstable for CW, and features controlled-carrier AM, which has no present-day use. However, the rig is attractive in appearance and ruggedly built. With crystal control it yielded a good note and some 70 watts of RF power on 144-MHz CW. The audio and VFO tubes were consigned to the junkbox.

One thing led to another, and I acquired a handheld FM transceiver. This expanded the workable population through repeaters. But the simplex paths, which were easy with the Seneca on CW, were a flop with the handheld — *even with a directional antenna.* I obviously needed more power. At this point, I devised a way to marry the two gadgets and the Seneca had its first introduction to FM.

The beauty of narrowband FM (in terms of the amplifier's response) is that nothing is happening. There's no change in total input or output power; linearity is of no consequence. Thus, an old-fashioned class-C amplifier works well. The problems in mating the FM transceiver and amplifier are reduced to those of providing output/input compatibility and send/receive switching.

These problems were resolved, and the result was 70 watts of RF on FM and plenty of simplex range. This output, which was achieved with less than 1 watt from the handheld, represented a much larger power gain than that of the typical solid-state "brick" amplifier.

Drive-point choice

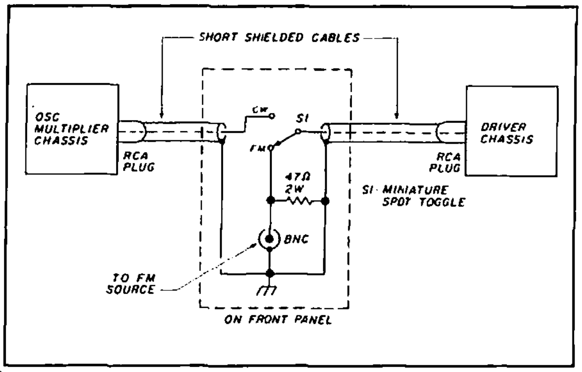
The Seneca uses a pair of 6146s in the output stage, with a 2E26 driver and a 6AN8 crystal oscillator/multiplier tube. The 6146 isn't designed for VHF use; it's hard to drive and somewhat tricky to neutralize and adjust. On the other hand, the 2E26 (which normally acts as a doubler from 72 MHz) drives easily and is well behaved. I decided to insert the FM transceiver output at the 2E26 grid.

This is a convenient drive point because the 2E26 grid tank is also the plate tank of the multiplier section of the 6AN8. The 6AN8 is located in the oscillator/multiplier subchassis and output is fed to the driver/final compartment through a short length of coax and RCA phono plugs. Interruption of this path provides direct access to the 2E26 grid with no tuned circuit present.

The voltage developed by 1 watt into 50 ohms is more than sufficient to drive the 2E26 as a straight-through stage at 144 MHz. The use of a resistively terminated drive avoids a tuned circuit and sidesteps parasitic oscillation at the common input and output frequency. A 47-ohm, 2-watt resistor does the job. In my setup (**fig. 1**), an SPDT toggle switch permits switching between FM

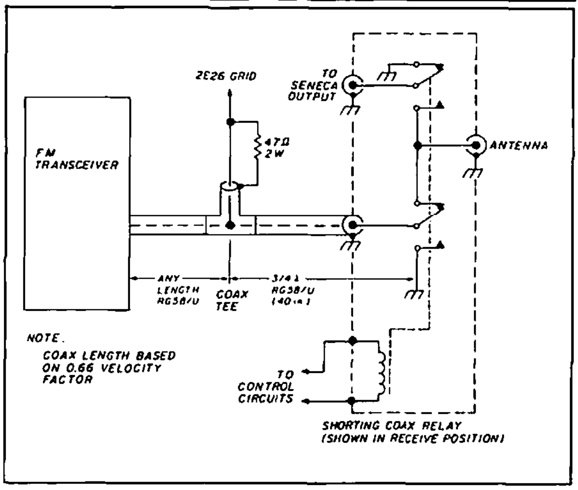
By Clifford J. Bader, W3NNL, 1209 Gateway Lane, West Chester, Pennsylvania 19380

FIGURE 1



FM drive insertion method.

FIGURE 2



Antenna switching.

and crystal-controlled CW. Those interested in FM only can dispense with this frill.

Antenna switching

The least obvious problem, as usual, turned out to be the most formidable. T/R switching involves getting the received signal back to the handheld, while inserting the amplifier during transmit. A DPDT coax relay is an obvious solution, but the only one available was a 24-volt DC, single-pole shorting type. I pressed it into service after adding an isolating section of transmission line. The combination does the switching with an insignificant loss of received signal.

Switching sequence

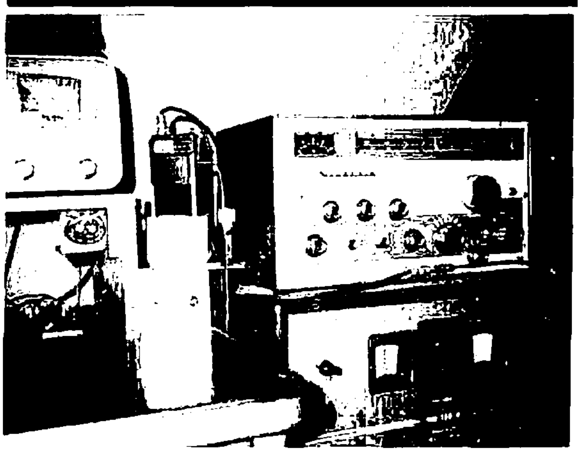
The system (**fig. 2**) works as follows: The transceiver input/output line runs to a T connector on the front panel of the Seneca, where it picks up the 47-ohm load in parallel with the 2E26 grid. From there, an additional three-quarter electrical wavelength (about 40 inches) of RG-58/U coax runs to the receive side of the relay. In the transmsit mode the relay shorts the coax, which then appears as an open circuit at the 47-ohm load because an odd number of quarter wavelengths intervene. (A quarter-wavelength section could be used but would be inconveniently short.) Thus, 47 ohms is presented to the transceiver and no drive power is lost.

In receive mode the 47 ohms represent a spurious load, which causes approximately 3-dB loss of received signal. With anything but already marginal signals, such a loss is negligible. In a desperate situation the T connector can be disconnected from the Seneca for receiving, but I've never found this to be necessary. The same basic approach could be employed with a non-shorting relay by using a half-wave line or multiple thereof.

Transmitter control

Another aspect of T/R switching is transmitter control. The Seneca uses a 115-volt, externally controllable AC relay to ground the center tap of the high-voltage supply during transmit periods. With voltage (but in the absence of excitation), final current is limited by a 6AQ5 clamp tube, which pulls the screen voltage to a low value.

PHOTO A



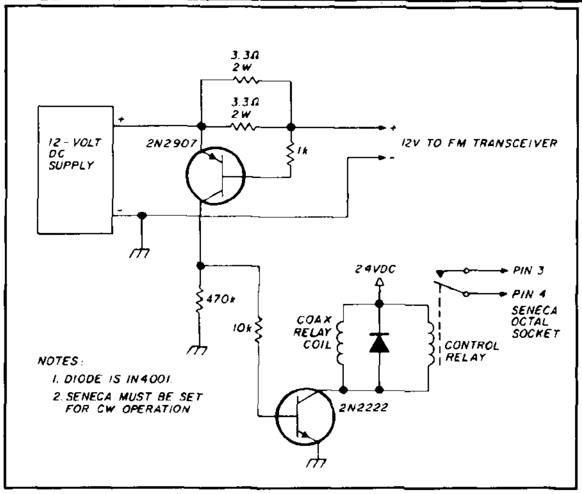
The Heathkit Seneca as a 2-meter FM amplifier for a handheld transceiver.

While it would be possible to keep the transmitter powered up and to merely switch the antenna relay along with the transceiver, there are several advantages to controlling the high voltage. First, the residual current in the final can have noise components, which might couple into the line through stray capacitance and mask weak signals. Second, the residual plate current is high

enough to push the 6146s close to their dissipation limits, so the rig runs much cooler if shut down during receive periods. Finally, the amplifier isn't loaded with the proper impedance during receive and under some conditions it might be subject to parasitic oscillations. These oscillations could damage both the amplifier and the transceiver front end.

There are a number of ways in which the amplifier

FIGURE 3



Transmitter control circuit.

power switching can be implemented. The optimum solution depends on the contents of your junkbox or the hamfest goodies you can find. I use a 24-volt DC auxiliary relay (with its coil in parallel with that of the antenna relay) to switch the Seneca's internal T/R relay. The latter is accessed through pins 3 and 4 of the octal socket on the rear apron.

Although it's quite feasible to manipulate a toggle switch to trip the relays and simultaneously work the handheld mike switch, snappy QSOs demand control of the relays from the mike. This can be done either by sensing RF from the transceiver or by sensing the increase in DC power consumption during transmit. The second approach is easy to implement if the transceiver is operated from an AC supply. It also avoids playing around with the RF path.

I use a 12-volt supply and an adapter with the handheld to provide the required 8.4 volts. The circuit (**fig. 3**) uses a 1.65-ohm resistance (two 3.3-ohm, 2-watt resistors in parallel) in series with the positive 12-volt lead to the transceiver. The transmit current of some 600 mA produces sufficient drop to turn on a PNP transistor with its base-emitter junction across the resistors. The PNP, in turn, activates an NPN transistor which energizes the relays. In receive mode, the current is insufficient to overcome the PNP junction drop and the relays drop out.

Operation

Some comments are necessary regarding the operation of the Seneca. On 2 meters, the 6146s are used above their self-neutralizing frequency, and the neutralizing wires are switched to augment rather than cancel the grid-plate capacitance. I found that the correct neutralization (achieved by bending the wires closer to or farther from the tube plates) held only for a limited range of final-grid and plate-tank tuning, and that tuning up at the opposite end of the band was an invitation to instability. The latter is evidenced by the erratic behavior of the final plate current as you tune through the resonant dip.

When the amplifier is tuned and neutralized at 146 MHz, performance is good over most of the band. You can check neutralization by loading the amplifier lightly, and adjusting the uncrossed set of wires symmetrically for a smooth dip as the final tank is tuned through resonance. **Caution**: There are lethal voltages present! Turn off the rig between adjustments and use an insulated tool to bend the wires.

Now load the rig to the normal plate current in the CW mode (I use 200 mA). The final grid current runs about 3 mA in my setup and the tubes show no sign of overheating. (Any reddening of the plates is a sign of impending disaster.) The amplifier works well with grid drive down to 1 mA or so, corresponding to only 150 mW from the transceiver.

The Seneca uses a front-panel adjusted hairpin loop for output coupling to the final tank. Loop reactance is canceled by a series "loading" capacitor. Because the inductance of the loop is increased by the inclusion of a 1-turn link to the 6-meter coil, it may be difficult to achieve sufficient loading of some coaxial lines — even at minimum capacitance. I found it helpful to solder a short piece of wire between the ends of the link. Obviously, the short would have to be removed for 6-meter operation.

Closing remarks

With appropriate modifications these techniques should apply to most of the older VHF rigs, like the Johnson Viking 6N2.

My resurrected Seneca (shown in **photo A**) has been in daily use for 4 years with excellent performance. The only difficulty has been in training the local gang to wait for the tubes to warm up after calling me on simplex. This minor problem has been more than offset by my being (perhaps) the only person on 2-meter FM with a pair of 6146s!

Article A **HAM RADIO**

THE WEEKENDER

Solo-16 Acoustic CW speaker

When operating CW, I find even high-quality headphones become uncomfortable at times. They also accentuate wideband receiver noise — a prime source of operator fatigue. To get a break from this, I decided to make a speaker especially designed for CW reception. I first tried the familiar trick of mounting a small transistor radio speaker on the end of a toilet paper roll. This "resonant tube" approach provided some acoustic selectivity, but I decided to explore the concept a bit further.

Design

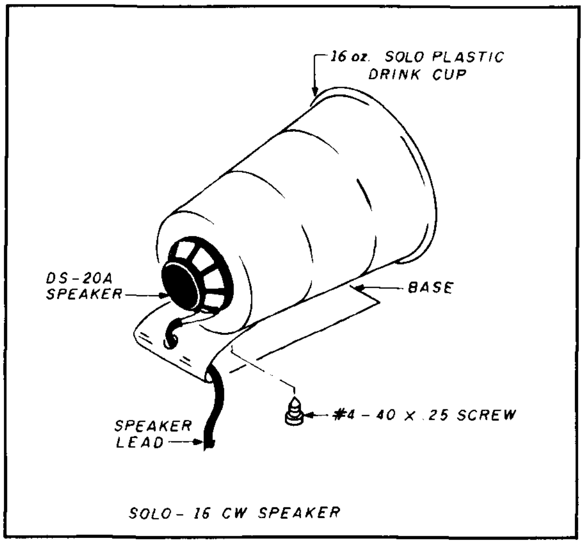
While looking through catalogs, I came upon a Star Micronics ultraminiature 20-mm speaker that specified a free-air resonance (F_S) of 700 Hz. I reasoned that coupling this particular driver to a horn-type enclosure with a corresponding resonance (F_C) of 700 Hz should result in a very high Q (frequency selective) speaker. After ordering a sample of the Star Micronics driver, I began the search for an inexpensive household item to serve as my horn. One of the first items I tested was a Solo® 16-ounce disposable plastic drinking cup. As luck would have it, this proved to be self-resonant to within 10 Hz of 700 Hz!

Construction and performance

When my sample arrived from Star Micronics, I carefully cut a hole in the bottom of the Solo cup and mounted the tiny driver in place with a super-glue adhesive. I then wired on a speaker cable and plug, and patched it into my homebrew QRP rig. (See **fig. 1.**) Listening to a busy 20-meter band, I observed that

By Rick Littlefield, K1BQT, Box 114, Barrington, New Hampshire 03825

FIGURE 1

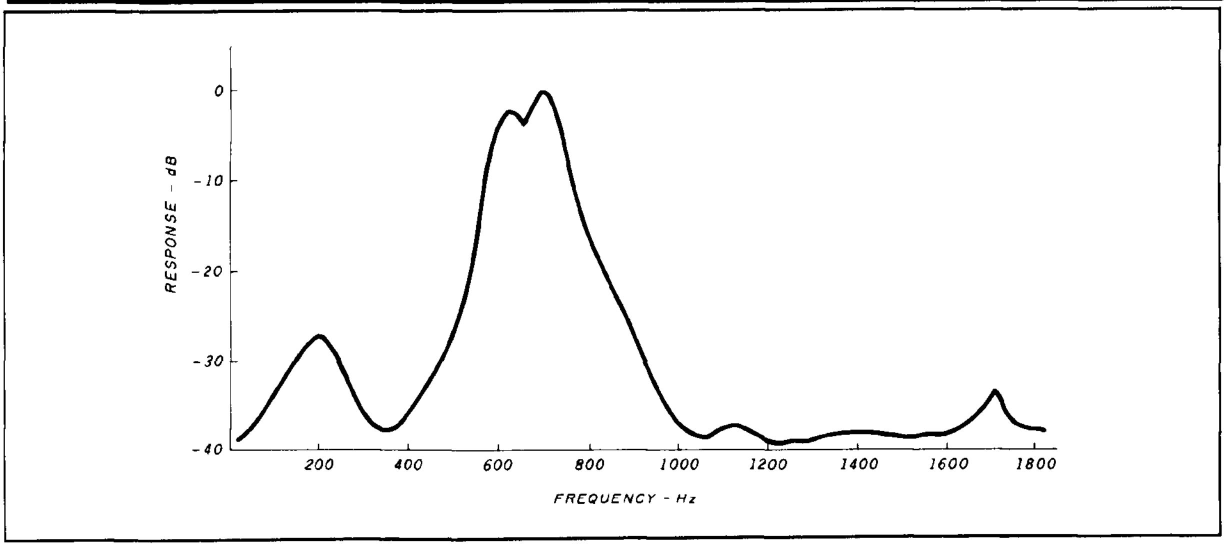


Construction details of the Solo-16 CW speaker.

There's only one precaution. While most commercial transceivers can deliver up to 5 watts of audio, the Star Micronics driver is only rated for 100-mW continuous tone (200 mW peak). To prevent driver damage, I suggest plugging into the transceiver phone jack (which is usually attenuated), or making an attenuator pad from fixed resistors. Don't worry about 100 mW being loud enough — the resonance and directivity (gain) of the horn will more than make up for any power reduction!

To complete my speaker, I made a triangular base from 1/32-inch aluminum, and attached the cup with no. 4-40 hardware. The acoustic dispersion pattern of the Solo-16 is quite directional, so I suggest adjusting your base to angle the horn directly toward your favorite operating position. This will provide the best audio path, and greatly reduce the annoying effects of phase distortion caused by room echo.

FIGURE 2



Audio frequency response of the Solo-16 CW speaker.

wideband noise had become virtually inaudible, while selectivity seemed dramatically improved. Signals were also a lot louder than through the transceiver's built-in 2-inch speaker.

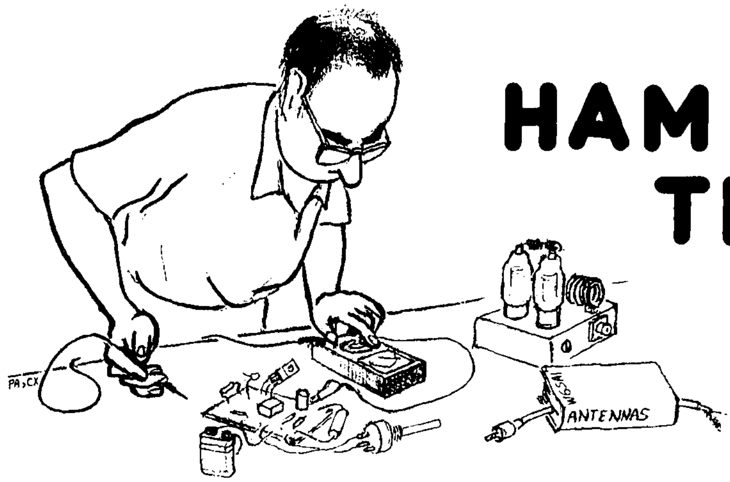
To get a more quantitative measure of what I was hearing, I connected an HP-3311A function generator to the speaker leads and positioned a Scott 451 sound-level meter 1 foot from the horn opening. **Figure 2** illustrates the resulting response curve. The −3 dB passband was approximately 150 Hz wide, with response dropping very sharply on both sides to nearly −40 dB. Most transceivers — especially those without dedicated CW filters — could really benefit from these numbers!

Conclusion

Over the past two months, the Solo-16 has proven to be a great accessory for CW reception. It takes the pressure off tired ears, puts a "final filter" on audio amplifier noise, and significantly improves the selectivity of most rigs. Best of all, the Solo-16 is simple, inexpensive, and incredibly easy to make. Give it a try!

Both the speaker driver ($3.50 plus $2.00 shipping and handling) and the complete kit ($10.00 plus $2.00 shipping and handling) are available from the author. *Ed.*

Article B **HAM RADIO**



HAM RADIO TECHNIQUES

Bill Orr, W6SAI

The "Invention of Radio"

The world changed for better or worse in 1865 when James Clerk Maxwell introduced his electromagnetic wave theory. This revolutionary concept fell on stony ground until 1875 when Professor Elihu Thompson demonstrated the existence of the waves in an induction coil experiment at Central High School in Philadelphia. The experiment wasn't widely publicized and Thompson doesn't seem to have carried out any further investigations. This field of discovery appears to have lain dormant until 1888 when Heinrich Hertz described his classic experiments with "aether" waves.

But it's not generally known that on May 23, 1885 Thomas A. Edison applied for a patent on "A New and Useful Improvement in Means for Transmitting Signals Electrically." Patent number 465,971 was issued to Edison on December 29, 1891.

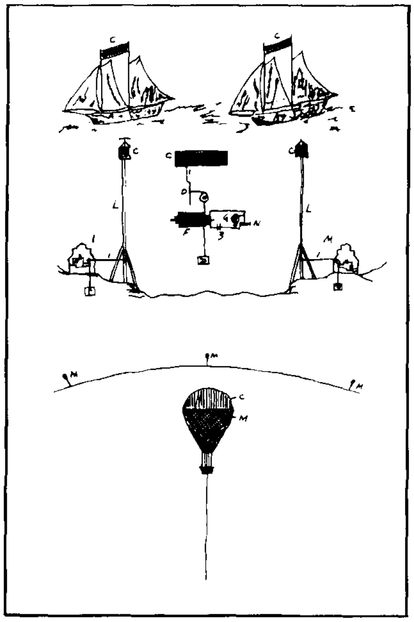
What was the meaning of this patent? Did Edison actually "invent" radio? Tom Clarkson, ZL2AZ, recently brought to my attention a story which created a ripple of excitement at the International Telecommunications Union Conference in Atlantic City, New Jersey in 1947.

Tom, who attended the conference, was kind enough to send me a reprint of the conference bulletin, *The Morning Electron*, dated September 12, 1947; it told the story of the "invention" of wireless.

According to Tom, the introductory remarks of the U.S. Assistant Secretary of State to those assembled referred to the magnitude of the task confronting the members, because of the great advances in radio communication since Marconi's invention. The next day one of the delegates of the U.S.S.R. took the floor to "correct an error." The real inventor of radio communication wasn't Marconi, he stated, but Alexander Popoff. He gave a vigorous address on the subject. A few days later an Italian delegate defended Marconi who, he said, did a lot more than just demonstrate primitive receiving and transmitting equipment.

The matter rested until a member of the U.S. Delegation produced a patent filed by Edison. It was dated ten years earlier than the experiments of either Marconi or Popoff, and two years before Hertz's work. The patent described a two-way radio communication system. A transcript of the patent was included in the *The Morning Electron*. After that, the conference dropped the subject and went on to more important matters.

FIGURE 1



Thomas Edison's "wireless" communication system (reproduced from original patent).

Edison's communication system

ZL2AZ mailed me a copy of the 1947 conference newsletter, now part the archives of the Antique Wireless Association. The Edison patent covered a signaling system that used two transceiver-like devices, complete with vertical antennas and ground systems (**fig. 1**[1]). Each transceiver had a high-frequency transformer with the secondary connected to the antenna and ground, an interrupter in the primary circuit, a source of power, and a code key. The motor-driven interrupter functioned as a commutator, generating a high-frequency wave. This device is similar to the early rotary gap-type transmitters used from 1897 to about 1910 and popularized by Poulsen of Denmark.

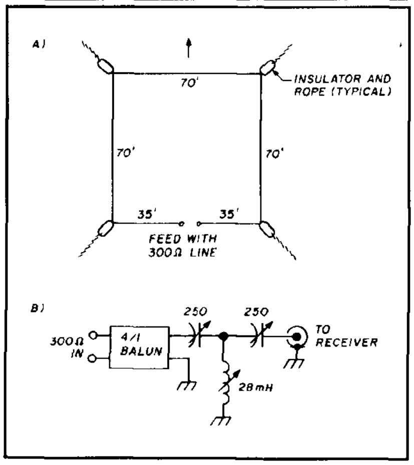
For reception, Edison placed a "polarized telephone receiver" in series with the secondary coil of the apparatus. Little is known about this device; however, it's thought to have been an ordinary telephone-style earphone in series with a crude oxide rectifier. The patent is vague on this point.

The patent shows that Edison understood the necessity of elevating his antennas to avoid the curvature of the earth. He also mentions signal absorption due to intervening objects.

The newsletter concluded that Edison had a clear concept of a workable radio system, and that he had foreseen many of the ideas that have taken years to perfect.

I find it interesting to speculate on this unusual patent. Why did it lie in the Patent Office for over six years before it was issued? Why didn't Edison build a working model of his transceiver and try out his novel idea? It's conceivable that Edison could have had a practical wireless system in 1885 — two years before Hertz's experiments. Because Edison chose not to continue with his brilliant idea, the honor of conducting the first radio communication experiments passed to Marconi, who started his transmissions in 1894.

FIGURE 2



Receiving loop of KD0SO for 160 meters. Height of loop above ground is 10 feet. Illustration (A) is view from above. Illustration (B) shows 4:1 balun and antenna tuner.

The low-level loop for reception

One of the problems in working DX on 160 meters is the high level of background noise. Many DXers have found they can't use their transmitting antenna for reception — the noise level is overpowering. Paul McClure, KD0SO, met this problem head on and evolved a horizontal receiving loop (**fig. 2**) that provides good signal-to-noise ratio. The loop's signal pickup isn't as good as that of a larger antenna, but noise drops off sharply. By adjusting audio gain of the receiver, you can bring the resulting signal up to the original level. Paul says that, out of the noise, he can pull weak signals that didn't seem to exist under normal circumstances. He says the antenna is comparable to a good Beverage wire. The loop, however, takes up less space and there are no terminating resistors to replace after a thunderstorm!

The above-ground height of the loop is about 10 feet. It's fed with a random length of 300-ohm ribbon line. Paul twists the line to balance it to ground. He has a twist about every 8 inches or so in a line nearly 100 feet long. The line is fed through a 4:1 balun and a simple antenna tuner to provide a 50-ohm termination for the receiver.

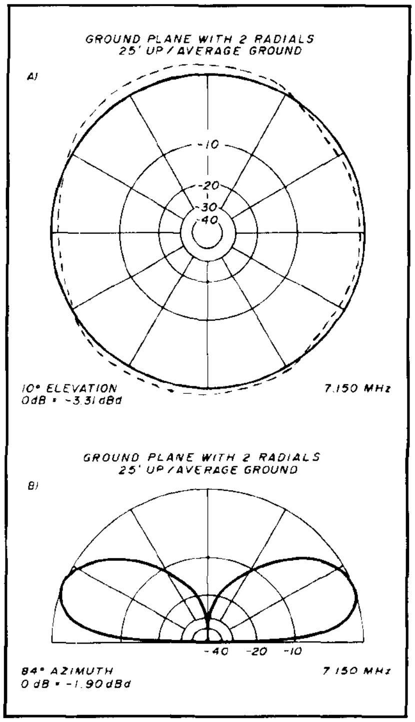
Two radials good, four radials better?

I seem to have stirred up some dust with my remarks about two versus four radials for a ground-plane antenna (*Ham Radio*, October 1988). A letter from Don Norman, AF8B, says that experiments he ran in 1982 on an elevated 147-MHz ground plane showed two radials were a considerable improvement over one, three radials showed no improvement over two, and four showed a slight improvement over three. He said his tests also showed conclusively that the radials served to decouple the feedline from the antenna.

Don's opinion is that HF multiband verticals planted in back yards around the world would probably perform much better if they were placed on rooftops and equipped with two radials for each band.

Bill Bringler, K5CSJ, ran the

FIGURE 3



Plane and elevation views of radiation pattern of 2-radial ground plane mounted 25 feet above "average" ground.

ground-plane program on his computer using MININEC and compared the field patterns of two and four-element configurations. The simulation was at 7.15 MHz, with the base of the antenna 25 feet above "average" ground (**fig. 3**). The radials dropped down to 15 feet of elevation at the ends. At a radiation angle of 10 degrees, the pattern of the two-radial design was omnidirectional within a fraction of a decibel. In the vertical plane, the angle above the horizon of the radiation pattern was less than 20 degrees. This corresponded to the pattern of the four-radial design. Bill concluded that there was no significant difference in operation between the two antennas. Bill also compared a ground-mounted vertical against the elevated two-radial design and found it about 1.5 dB worse at an elevation angle of 10 degrees. His conclusion: "A two-radial ground plane, when elevated, works just fine!"

And how about radial length?

Collin Stiteler, KE6VZ, isn't convinced that ground-plane radials should be 5 percent longer than the radiator, as some conventional wisdom seems to indicate. I checked my references and found that my various antenna books, plus the *ARRL Radio Handbook*, all call for the radial length to be the same as the antenna length. (At least I seem to be consistent!) Different ARRL publications refer to radials 5 percent longer than the antenna and also to radials the same length as the antenna, depending upon the publication. Obviously there's *not* a meeting of the minds on this subject. Offhand, I would think that it doesn't make any difference as far as results are concerned. I cut my radials equal in length to the antenna and let it go at that.

Collin points out that a CB whip antenna mounted over quarter-wave horizontal 10-meter radials and matched with a capacitor across the feedpoint makes an excellent 10-meter installation with a near-perfect match to a 50-ohm coax line. Collin used a 56-pF capacitor from antenna to radials. Not a bad idea for a "quick and dirty" 10-meter antenna.

Two new handbooks!

I've just received two new handbooks that I'd like to tell you about. The first one is *W1FB's Antenna Notebook,** written by Doug DeMaw and published by the ARRL. This book covers many simple do-it-yourself antennas. There's no high-level math in the book; it's a plain language approach to a subject that's of great interest to newcomers and old-timers alike.

DeMaw discusses many interesting wire antennas like the popular G5RV antenna, multiband dipoles, and trap dipoles. Single wire, loops, and vertical antennas are covered in detail. The scheme of using a tower or mast for a vertical antenna is discussed, along with the tuning and matching procedures required. The efficient W1FB compact 160-meter vertical antenna seems to be the answer for the low-band DXer trying to be loud when confined to a city lot! The 160-meter "snake" antenna (of which I had heard rumors) is shown as well as other low-noise receiving antennas for the top band.

Antenna matching devices and baluns are discussed, as are simple antenna measuring techniques, but the Amateur looking for VHF antenna information will be disappointed. The book is like a low-pass filter — it cuts off at 30 MHz! No matter; there's enough juicy information about 1.8 to 30 MHz to maintain your interest to the last page.

The second book resembles a high-pass filter, as it concentrates on the spectrum above 50 MHz. This is my new book, *All About VHF Amateur Radio*, published by Radio Publications, Inc.** It's written for the beginning Amateur and the newcomer to the VHF bands. However, there's enough good information on VHF antennas, the cause and cure of VHF RFI and TVI, moonbounce, satellites, and DX propagation to interest even the jaded VHF old-timer. Modesty prevents me from extolling the virtues of the work, but I wanted to bring it to your attention!

The F.C.C. did me in on one matter. Just after the book came off the press, my reference to the 220 and 225-MHz Amateur band was jeopardized because of the attempted usurpation of the low end of the band. I hope, for my sake and for the sake of Amateur Radio, that I won't have to change this reference at the next reprinting!

A final wrap-up

Thanks to all who have entered my "Dead Band" Quiz. Closing out the earlier quizzes: congratulations to Dan Curtin, KF4AV, who correctly identified the Sherlock Holmes quotation, and to Lewis Finch, W4VRV; Marty Davidoff, K2UBC; Bruce Williams, WA6IVC; Alvin Borne, W6IVO; Dan Curtin, KF4AV; and "Herb", WL7BIL who knew the quotation from "Catcher In The Rye," by J.D. Salinger.

Occam's Razor, locomotives, and hornets

Early in the 14th century, the English philosopher William of Occam proposed that, of all the possible explanations for certain phenomena, the simplest explanation should be considered first. A fine example of Occam's Razor (cut the problem to the bone) was the Dead Band Quiz about the colliding locomotives and the flying hornet.

The correct answer regarding the distance the hornet flew between the locomotives as they sped towards each other on a collision course is 300 miles. A lot of readers came up with this number.

It's interesting to look over the many replies I received to this little problem. In general, there were four approaches: the intuitive, the graphical, the mathematical, and the scientific. Some readers solved the problem in more than one way.

*Available from the **HAM RADIO** Bookstore for $7.95, plus $3.50 shipping and handling.

Available from the **HAM RADIO Bookstore for $11.95, plus $3.50 shipping and handling.

The majority of readers chose the mathematical approach, i.e., finding the time to collision by dividing the travel distance by the closing speed (60/80 = 0.75 hours). If the hornet flies at 400 miles per hour for 0.75 hour, he covers 300 miles.

A list of all who solved the "Dead Band" problem is available from *Ham Radio* for an SASE. (The list includes only those whose letters were received in the first 10 days after magazine publication. I'll pick up later entries in my next column.)

I think this magazine is fortunate to have readers of stature and I'm pleased to receive such interesting and informative "feedback." Thank you! I'll continue to toss some little brain teasers at you from time to time. I hope you enjoy them!

The Dead Band Quiz

Since everyone did so well on the locomotive/hornet quiz, here are two simple problems submitted by column readers. Sharpen your pencils and go to work!

Quiz no. 1 was submitted by Joe Mehaffey, K4IHP. A black box has five terminals. Measured with an ohmmeter, the resistance between any two terminals is 1 ohm. Joe knows the box contains only resistors. What is the circuit inside the box?

Quiz no. 2 was submitted by Joe Caffrey, W3DZH. A ham has a glass jar filled with transistors in his junkbox. He decides to count them and finds that if he removes them from the jar two at a time, he has one transistor left in the jar when he's finished. Unfortunately he forgets his count, so he dumps the devices all back into the jar. This time he removes them three at a time and winds up with two left over. Distracted by a VHF opening, he again forgets his count, replaces the transistors in the jar, and removes them four at a time to discover at the end he has three left in the jar. This process is repeated three more times. When he removes them five at a time, he finds four left over; when they are taken out six at a time, five are left; and when taken out in groups of seven, six remain.

Having managed to forget the exact count six times now, our hero decides to apply simple mathematics to find the smallest number of transistors that could have been in the jar. What is that number?

Joe says, "My initial solution involved 'cheating' by programming a VIC-20 computer to count upwards from 11 and test each integer until one was found that would satisfy the given conditions. Hours later, the simple and elegant solution struck me as I was driving down the road in my car!"

To save your postage and time, I'll give the answer to these little problems next month. Stay tuned.

References

1. *The Morning Electron*, Volume One, No. 67, International Telecommunications Union Conference, September 12, 1947, page 7.

Article C **HAM RADIO**

Station Control Node

EXPAND YOUR VERSATILITY WITH THE SCN

By Barry Buelow, WA0RJT, 4110 Emerson Avenue, N.E., Cedar Rapids, Iowa 52402

Now you can use a terminal, computer, or even a mailbox to monitor and control your equipment with this packet radio Station Control Node (SCN). Packet radio provides a reliable link and the SCN controls the equipment. You can stay at home and use packet to find out what's going on up on the mountain or out among the corn stalks. Nearly any task you can do manually, you can now do remotely.

Figure 1 shows a typical SCN installation. You establish a connection with the remote TNC and automatically access the SCN. Designed to operate at unattended sites, the SCN lets you monitor door switches, tower lights, AC line status, temperature, RF power, SWR, or battery voltage. It lets you control antenna selection, frequency, power amplifier operation, and other functions. The Station Control Node is a data acquisition and control system that works in conjunction with a packet radio Terminal Node Controller (TNC). An SCN consists of a microcomputer and a variety of I/O buffers that you can access via packet.

Many SCN components incorporate high levels of integration to perform sophisticated functions. This lowers the parts count, reduces board size, and eases system startup.

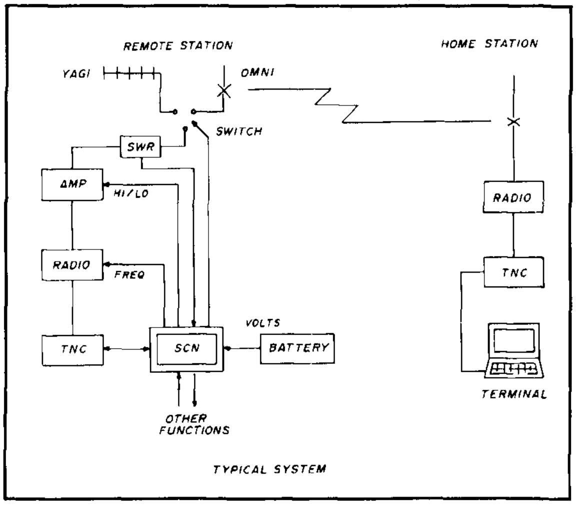
Hardware description

The system's design is straightforward. Functional segregation facilitates trouble-shooting, should it be necessary. The components mount on two printed circuit boards. The main computer circuits are on one card and all the applications you want to control will connect to the buffer card.

MCU card

All of the digital ICs are low power CMOS, including the MC68HC11 processor. Motorola did a good job of incorporating desirable features in this single-

FIGURE 1



Typical system.

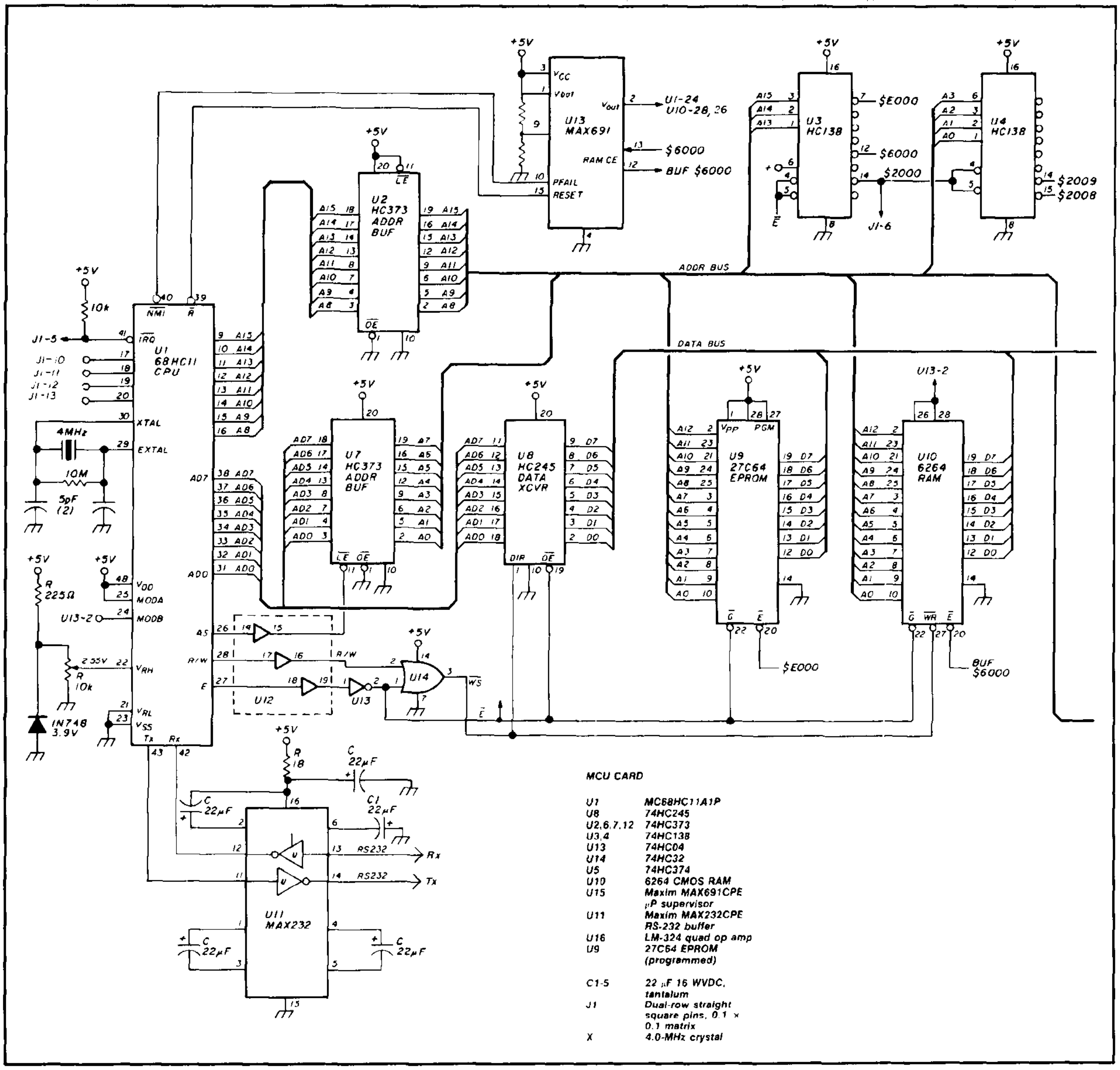
chip microcomputer (MCU). It contains the CPU, 256 bytes of RAM, 512 bytes of EEPROM, serial port, A/D converter, timers, and more. (These functions used to require a large amount of board space.) A single crystal, which is a multiple of the baud rate, serves as a clock for both the MCU and the internal serial port clock.

Operating in the expanded mode, the MCU configures the ports as an external data and address bus. These buses access the EPROM and hardware ports.

The MCU assembly consists of the MC68HC11, a 27C64 EPROM, buffers, address decoding, and two ports. A DIP switch identifies the type of TNC and selects the setup mode. A 7-segment LED display traces the software activity for debugging purposes. To provide for some expansion, a socket is available for a 6264 CMOS RAM (8K × 8). However, the current version of software doesn't require external RAM.

A Maxim MAX232 serves as the RS-232 interface.

FIGURE 2



MCU card schematic. (All unused inputs of U12, U13, and U14 should be tied to ground.)

This chip uses only +5 Vdc and generates ±10 Vdc by a series of choppers and external tantalum capacitors. The line drivers and receivers then operate at the proper ±10 volt levels.

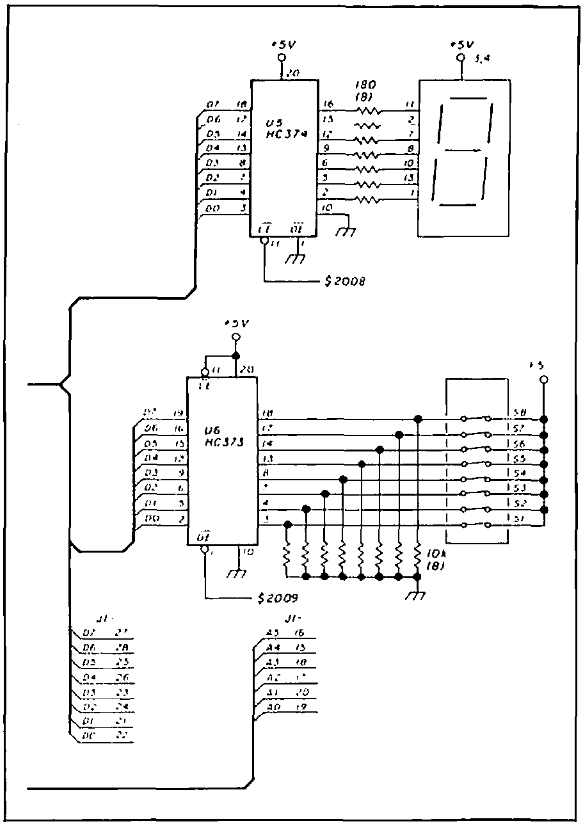
Another Maxim part, the MAX691, monitors the +5 Vdc line. In the event of a power failure or brownout, the chip will signal the MCU to halt operation. This prevents erroneous operation during power up/down which might corrupt the RAM data. The chip also switches the optional backup battery to the MODB line of the MCU, maintaining RAM data. (See **fig. 2** for a complete schematic.)

Buffer card

A single external power supply of at least 8 volts AC or DC will operate the entire unit. The SCN requires about 200 mA. You can use a modular AC line adapter or power the unit from a 12-Vdc source.

There are two ports (8 bits each) with buffers for discrete inputs. A network clamps the input to the CMOS logic levels and provides protection from lightning-induced spikes. Applying a voltage of +5 Vdc or more will provide a logic 1 to the MCU. A low logic level results from either applying a ground

FIGURE 2



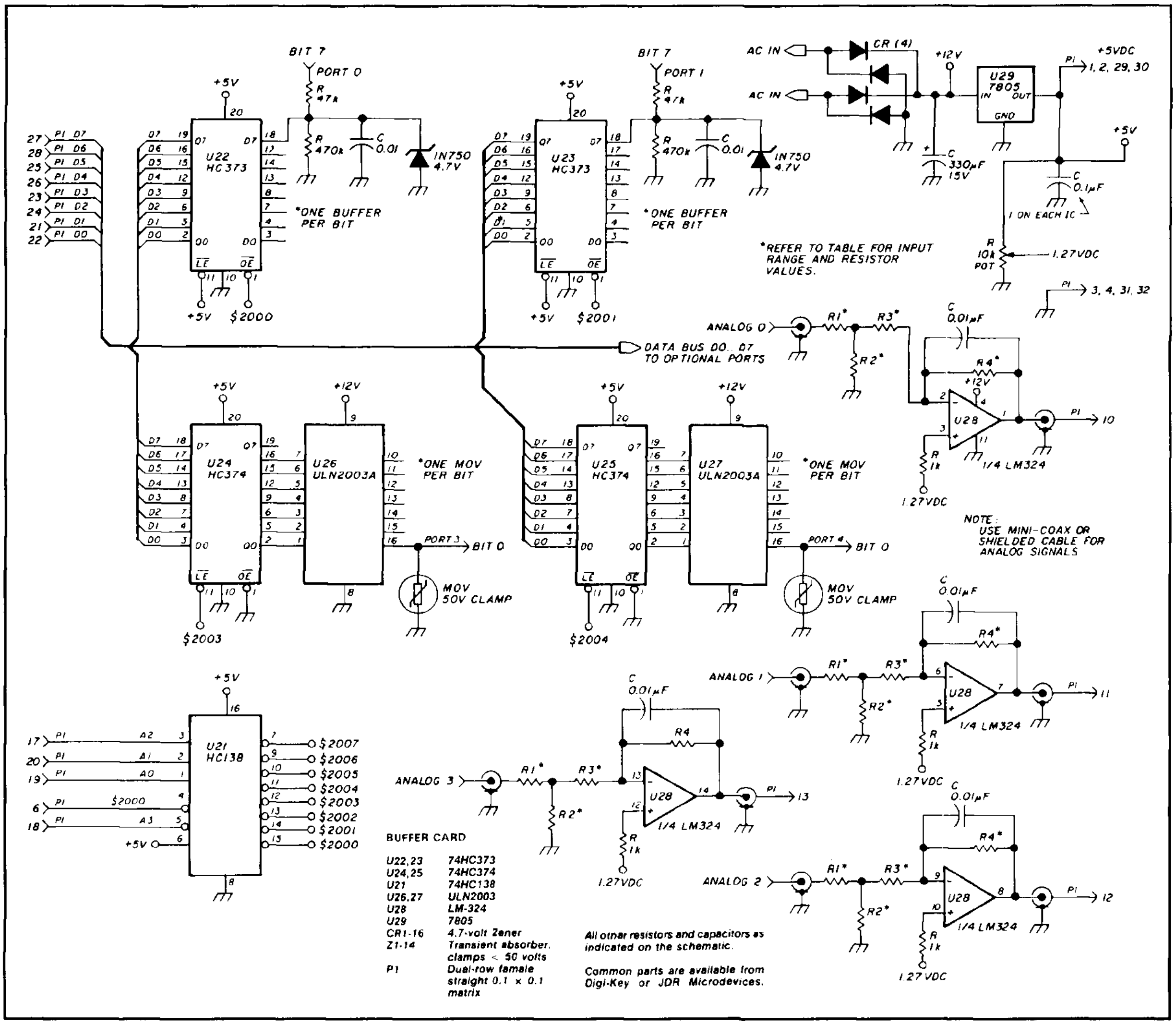
or leaving the input open. This allows you to connect directly to signals operating over the range of + 12 Vdc to ground. The SCN provides two ports with output drivers (7 bits each). A 74HC374 latches the data and drives a ULN 2003A which contains 7 Darlington pairs. These outputs are either open or sink current to ground. Note the logic here. When you set a bit, the SCN enables the driver which provides a ground, turning on the external device. At power up, all drivers are commanded to a logic 0. You can wire the two uncommitted bits to any unique drivers you wish to build.

Two additional ports can be installed with either 74HC373s or 74HC374s. The board location configures the port as either an input or output. You can build whatever interface you desire on these ports.

There are four analog inputs which have individual buffers and scaling. The inputs are single ended and feed into an LM-324 quad op amp. A voltage divider precedes the op amp for input voltages greater than + 5 Vdc. You can use the high range to monitor a battery; the low range is suitable for monitoring SWR or forward power. The maxim ..n input voltage translates to zero volts out and zero volts in becomes + 2.55 volts out.

If the input is greater than + 2.55 volts, the voltage

FIGURE 3



Buffer card schematic.

divider must reduce the signal. In Table 3, the +15 volt signal is divided down to +2.55 volts using a divider current of 1mA. The buffer gain is −1 and the software inverts the signal again.

Figure 3 shows a complete schematic.

Software

The software has a good mix of user-accessible functions and self-maintenance tasks. These should take care of most of your remote control needs and eliminate a few trips to the mountain top.

Many program functions aren't visible, but are essential to SCN operation.

- Every 31 mS, the MC68HC11 internal hardware generates an interrupt which triggers the background task.
- Software timers monitor user activity and reset the heartbeat monitor periodically.
- A foreground routine monitors flags set by the various interrupts and transfers control to the proper servicing task. Limiting the number of tasks helps fit all of the operation into the 256 bytes of RAM, so only one task is active at a time.

Foreground tasks perform these functions: user sign-on message and menu, long/short menu, recognition of one-character commands, traps for illegal commands, and a long delay on power up so the TNC can recover first.

The program measures the analog inputs with each program cycle. Depending on the state of the PTT line, the A/D values are stored in RAM as TX or RX data.

When you give the VOLTS command, the two values taken from RAM represent the most current data in both modes. This operation is necessary to observe RF power and power supply voltage drop during TX.

One interesting program feature is the channel statistics display. The SCN samples the TNC's DCD and PTT lines 30 times per second and computes their duty cycles. The ACTIVITY command shows this record, in 1-hour intervals, for the previous 12 hours. You can see when the BBS forwards late at night and the local activity picks up after 5 p.m.

You can set or clear individual port's bits one at a time with the S (C) command. The bit is used as a mask to modify the output port's image in RAM; then the data is copied to the port. If you change only one bit, the other functions on that port won't be affected by the new data. You don't have to know the previous settings for all other bits in a port. The SCN program reads the ports so you can see the new data and acknowledge it.

If a mailbox sends a script to the SCN at the beginning of a forward, the function will operate without knowledge of the other bits. When forwarding is completed, the mailbox can clear the desired bits.

A level of protection exists for Port 3 (output). You need a password to use this port and access the additional commands. Because of the protection feature built into Port 3, it would be inadvisable to describe the password implementation procedure here. I will, however, send information about adding this procedure to the system to anyone who orders the program object code.

Operation

To access the SCN from any packet station, simply establish a connection. This is exactly the same procedure you'd use to talk to another station, but the SCN will reply instead of another ham. The SCN recognizes the "*** Connected to xxx" message from the local TNC and responds with a sign-on message and menu. You can select an item from the menu:

- Examine the input ports.
- Command output ports.
- Review channel activity statistics.
- Monitor the analog inputs.

Refer to **tables 1** and **2** for more detail.

Several commands require only one letter: A, D, H, P, and V. You just send the letter (upper or lower case) followed by a carriage return. The SCN will respond with the information you requested.

You must enter the port and bit numbers to access commands that address a specific function. To enable an external device connected to the SCN you'd send S45 with no spaces. The first digit (in this case 4) indicates the port number and 5 indicates the bit of that port. Strings which are longer or shorter than three characters are invalid and don't affect the ports.

TABLE 1

Table 1. Menu

A	Activity: displays DCD and PTT statistics for the previous 12 hours.
Cpb	Clear bit port: clears (logic 0) the bit b of port p. Example: C10 clears bit 1 of port 0.
D	Disconnect.
H	Help: a short description of the commands.
P	Ports: returns hexadecimal equivalents of ports.
Spb	Set bit port: sets (logic 1) the bit b of port p.
T?s	TNC inquiry string: asks the TNC for the current value of parameter string s.
V	Volts displays all 4 analogs during both TX and RX.
X=n	Answer to problem, a 2-digit number, allows access to restricted commands.
X?	Requests a problem.

Port assignments: 0,1,2 & 3 are inputs; 4,5,6 & 7 are outputs. Bits are numbered 0 to 7; 0 is the least significant bit.

TABLE 2

Table 2. Restricted commands

T=s	TNC command, sends the string s to the TNC.
Z=n	Key number.
Z?	Displays the current key number during setup.

Static precautions

Both cards use delicate CMOS devices which require proper handling. Store loose devices in antistatic foam or bags. During assembly, lay a sheet of aluminum foil on the workbench. Use a wrist strap with a 10-meg resistor in series to connect yourself to the foil. Four items should be at the same electrical potential: the circuit boards, the components, the soldering iron, and you.

MCU card assembly

Use sockets for the MCU, EPROM, and the two Maxim parts. Solder in all other components on the MCU board, including the HC devices. Be sure to check for shorts between pins. Before installing the MCU and EPROM, apply +5 Vdc to the card and monitor the current. It shouldn't exceed 200 mA. For greater precision, you may want to install 1-percent resistors in all the analog signal processing circuits.

As a monitor, the 7-segment display shows a number indicating the task that is currently active. The display should count to 4 in about 4 seconds at power

TABLE 3

Table 3. Analog scaling matrix

Input Voltage	0.5	1.5	5	15
R1	short	short	2.43 k	12.4 k
R2	open	open	2.55 k	2.55 k
R3	10 k	10 k	249 k	249 k
R4	51.1 k	16.9 k	249 k	249 k
Divider	1	1	2	5.9
Gain	-5.1	-1.7	-1	-1

Note: All above values are standard 1-percent precision resistors.

up. If the display doesn't show the proper function, you'll need a scope or a logic probe suitable for CMOS.

To trouble shoot, check the applied voltages. See if reset has gone high and check the oscillator. The EPROM should be getting a series of chip enables. Determine if the MCU is running. Check for shorted or open address and data lines. Very little can go wrong with the circuitry and stop the processor.

Buffer card assembly

Build the power supply section first. Use a resistor to simulate the load of the MCU and buffer cards (200 mA). Apply power and check for proper supply regulation.

Determine the amount of I/O you want to build, multiply by 2, then put the components on the buffer card. You can test the discrete buffers before you install the 74HC373s by strapping the inputs high/low and observing their operation with a scope. You'll have to decide what signal levels you wish to monitor and scale the analog inputs using the values in **table 3**. Input signals greater than +5 volts require a divider stage. Scaling for 15 volts allows some headroom for battery chargers and power supplies running a little above normal. Adjust the reference voltage pot for 2.5 Vdc at the CPU.

Wiring

Maintain good static precautions and mount the boards in an environmentally tight enclosure. Construct four cable bundles from the cards to the chassis connectors — one for the power input, a second for the signals to the TNC, a third for the digital I/O, and a fourth for the analog inputs. Use shielded cables on the analog inputs and maintain good cable bundle separation. This will prevent coupling of the serial I/O noise to the outside and limit potential lightning problems.

Wire discrete lines and analog inputs with shielded cables. Be sure to terminate the shield at both ends. This level of protection is required because lightning strikes can induce destructive voltages.

Mate the two cards, but don't make any connections to the external devices. Turn on the SCN and watch the display for proper operation.

TNC hookup

For RS-232, connect only pins 2, 3, and 7 of the TNC. Set the TNC for 1200 baud, 7 data bits, even parity and 1 stop bit. Use a terminal to set the callsign and verify TNC operation. If you are using a TNC-1, be sure to perm the data and set the dip switch to use the stored values during initialization. Other TNC AX.25 parameters should conform to standards established in your area. Refer to **table 4** for some specific TNC settings and **table 5** for some specifics on the SCN.

TABLE 4

Table 4. TNC Settings

MON	OFF	XFLOW	ON
MCON	OFF	CONOK	ON
MALL	OFF	TRACE	OFF
FLOW	ON	BEACON	0
ECHO	OFF		

TABLE 5

Table 5. Specifications

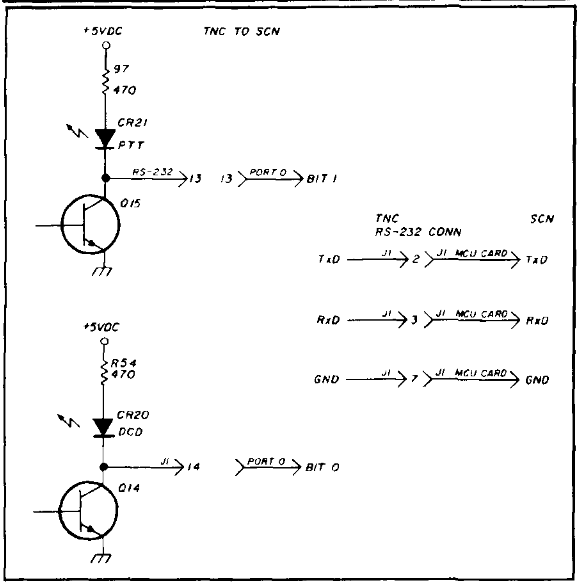
Serial Bus:	RS-232, 1200 baud, 7 data bits, even parity, 1 stop bit, on board ± 10 volt generator, recognizes TAPR TNC commands.
Inputs:	Discrete inputs: 2 ports, (16 bits). Analog inputs: 4. User determines scaling, 8-bit resolution.
Outputs:	Discrete: 2 ports (14 bits) with high level driver (200 mA/bit).
Additional ports:	2 uncommitted ports (16 bits). User selects type of buffering or drivers.
Power input:	8 to 15 volts, AC or DC @ 200 mA.
Size:	2 boards, each approximately 6.5 × 4.75 inches.

There are enough unused RS-232 connector pins on both the TNC-1 and TNC-2 so that two can be freed and used for DCD and PTT. This allows a single connector to make all TNC to SCN circuits. Break the connector pin to ground lines in the TNC. Now wire from the connector pins to a point which goes to ground to light the appropriate LED. If you get the wrong side of the LED or current-limiting resistor, the signal won't go low enough. Use a meter to determine the proper point in your TNC. See **fig. 4** for more details.

Setup

You'll need a null modem adapter to connect a terminal to the SCN. This swaps the functions of pins

FIGURE 4



TNC to SCN interconnection

2 and 3. The SCN configuration is Data Terminal Equipment (DTE) and the terminal is Data Communications Equipment (DCE) during setup. With the SCN turned off, set dip switch number 4 (bit 3) to on and apply power. The SCN will come up in setup mode so you can enter the key number using the Z= and Z? commands. When you've completed this step, remove power and set switch number 4 to OFF for normal operation. The null modem adapter isn't required for normal operation with the TNC.

If everything looks good, connect the TNC to the radio and the SCN to the various equipment. Apply power to the TNC and then to the SCN. To test the system, use another packet station and perform a connect request and select from the menu items.

Conclusion

This system is simple to operate and has a great deal of utility. Its variety of inputs and outputs should meet most of your needs. The system's real flexibility is demonstrated with each unique implementation that adds a little different flavor to packet radio.

Software and pc boards

If you'd like the program object code, it's available in two forms — a programmed 27C64 which works directly in the circuit ($12) or an IBM compatible PC disk with the files in both Motorola S record and raw hex format ($5). You may copy and distribute the object code in either form. A set of double-sided pc boards is also available for $50. I can also send you the CPU and Maxim parts. For more information, write me at the address listed at the beginning of this article.

Article D · **HAM RADIO**

THE HAM NOTEBOOK

The 12-meter "garage plane" antenna

Are you weary of trying to explain your compromise antenna for the new 12-meter band? If you yearn for an antenna dedicated to this band you might want to try my idea. Some of the attractive assets of the "garage plane" are:

- Low cost (ridiculously low)
- Simple construction
- Easily tuned
- Respectable SWR
- Unobtrusive

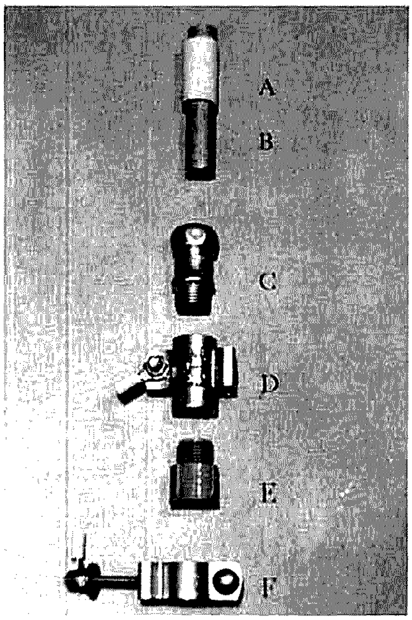
I got the idea of using my garage as an antenna base when I ran out of room to mount antennas on my modest suburban lot. My garage was the only unadorned area left. It also has a hip roof design allowing installation of a drooping ground radial configuration.

The major cash outlay for this project was the purchase of a 10-foot length of 1/2″ thin-wall conduit. You can buy it at most hardware and building supply stores for less than $3. The other parts will probably cost you about another $3.

The first construction step is probably the most difficult; it's making the decision to drill a 3/4″ hole through the garage roof. After you've done this, the rest is relatively easy. (See **photos A** through **C** for construction details.)

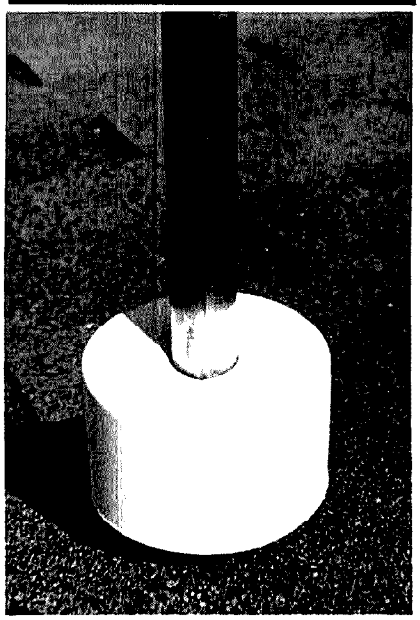
The antenna is a basic ground plane, nothing new. The 8 radials are cut to 9′ 2-1/2″. Four are stapled to the underside of the hip ridge rafters. The others are spaced equally between the ridges and stapled to the underside of the midpoint rafters. I made the radials out of scrap 12-gauge stranded wire. Cut the radiator to about 9′ 6″ initially; then follow standard antenna pruning procedure to obtain minimum SWR. (I used a copper-tubing cutter.) I got optimum resonance at a combined

PHOTO A



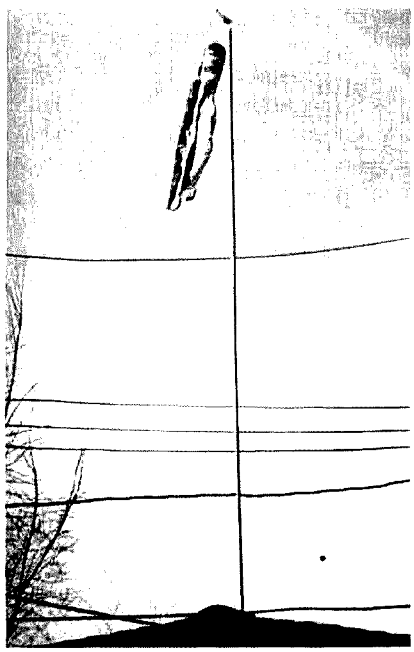
Component line-up: (A) Shrink-fit insulation tube, (B) 1/2″ thin-wall conduit, (C) 1/2″ conduit compression fitting, (D) 1/2″ coupling with 3/4″ conduit hanger and 1/4-20 bolt and nut, (E) 1/2″ PVC to pipe fitting, (F) 3/4″ conduit hanger with 1/4-20 bolt and nut. Note: The bolt in item D is used for connecting the center conductor of the coax. The bolt in item F is used for connecting the assembly to a board under the roof, as well as for the shield of the coax and the 8 radials.

PHOTO B



Rainproofing. A cap from a can of spray paint serves as a water shield.

PHOTO C



The radiator. Note the wind sock. Powerlines in the background are 35 feet behind the antenna.

(conduit plus fittings and unshielded coax) radiator length of 9′ 2-1/2″. This meant a conduit length of about 8′ 10-1/2″. The SWR at this length was 1.2:1 across the entire band.

Now before closing the garage door and returning to the shack to verify your antenna's on-the-air performance, seal the hole in the roof with roof patch cement or silicone rubber. As an added weatherproofing measure, you can use the plastic cap from a spray paint can. Punch a hole in the center of it with a scrap of the conduit. Slide the cap over the conduit (right side up) until it's just above the roof shingle and then seal it in place.

Performance tests indicated the following:

Item Tested	Garage Plane*	Inverted V dipole**
Noise level	Slightly above	Reference
Directionality	Omni	Almost Omni
TVI***	None	None
Signal Received (Average)	+1 1/2 S-units	Reference
Signal Transmitted (Average)	+1 1/2 S-units	Reference

While these statistics show that perhaps the antenna excels more in uniqueness of construction than it does in performance, the +1 1/2 S-units consistently reported can't be ignored. Keep in mind that this antenna was erected primarily as a general purpose device to enable 12-meter operation without resorting to antenna tuners and makeshift antennas.

I hope you enjoy building and using your 12-meter antenna as much as I've enjoyed mine. The antenna is so good that it even defied the unwritten law, "An antenna's performance rating is directly proportional to the adverse weather conditions encountered during installation." The antenna was erected on a clear, warm, and sunny day and it works great!

Richard St. Amant, W8PDV

*Stations worked during the test ranged from South Africa, Greece, the Caribbean, and California.
**The feedpoint of the inverted V antenna was at an elevation level with the center of the garage plane radiator, about 16 feet above ground.
***The TV antenna on the set used for TVI verification is located 35′ from the center of the garage plane. TV antenna height is 16 feet above ground. The TV set was located next to the transceiver. TV transmitters averaged 20 air miles away.

Article E

QSK MODIFICATION FOR THE TRIO-KENWOOD TL-922 AMPLIFIER

By **Richard L. Measures, AG6K,** 6455 La Cumbre Road, Somis, California 93066

The TL-922, while a beautifully constructed amplifier, is not suited for full break-in operation like AMTOR or QSK-CW. For those who enjoy working SSB/VOX, a QSK modification is worthwhile because it reduces relay noise.

In this article I'll describe one method of converting the TL-922 to QSK. I also have available a companion article on circuit improvements other than QSK for the TL-922. A list of parts suppliers is included.*

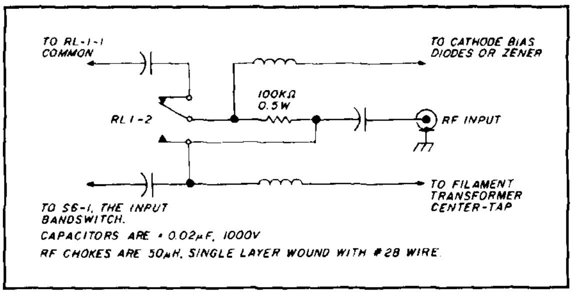
QSK

There are two popular methods of RF switching for QSK: PIN switching diodes and high-speed relays. The PIN diodes are quieter and faster, but they're also subject to damage from electrostatic discharges like lightning in the near field of the antenna, and their related circuitry is complex to construct. High-speed relays aren't as fast as PIN diodes, but they can do the job of switching the amplifier from receive (RX) to transmit (TX), or TX to RX, in about 3 mS. This is fast enough for Amateur Radio applications. The high-speed relay's acoustic noise problem can be minimized with an appropriate relay mounting technique.

You can perform TX/RX cathode-bias switching in the TL-922 with an optoisolator driving an NPN power transistor. An alternative method is to use two 50-μH RF-isolating chokes and three 20-nF (0.02 μF), 1-kV, DC-isolating capacitors on the input relay contacts (see **fig. 1**). These components allow the input relay contacts to simultaneously switch the RF input and the DC cathode-bias currents. I'll show both methods.

There are two manufacturers of suitable (*vacuum*) high-speed relays that will handle 2450 watts (7 A in a 50-ohm circuit) up to 32 MHz. They are Kilovac, Inc., Santa Barbara, California and Jennings Radio, Inc., San Jose, California. These relays are the Kilovac HC-1 ($93) and the Jennings RJ-1A ($95); the two relays are virtually interchangeable. When driven by a 26-volt source, they are rated at ≤6 mS and ≤8 mS switching speeds, respectively. The rated speeds tend to be on the conservative side of each relay's measured capability.

FIGURE 1



Circuit showing one method of providing QSK operation. This method uses two 50-μH isolating chokes and three 0.02-μF isolating caps on the input relay.

Before any relay can actuate, current must flow in the relay's coil. In order for this current to flow, the inevitable inductance in the coil must be overcome. Theoretically, this process can take place in no time at all if a perfect constant current source is used to drive the coil. Unfortunately, this requires a current source that's capable of infinite voltage at T = 0. Infinite voltage, besides being a large order, is going to cause a big problem for the insulation in the relay's coil and anything else in the same room! It just isn't practical.

When driven by a voltage-limited current source, a relay can be made to switch faster without the risk of coil insulation damage. You can construct a voltage-limited current source by placing 600 ohms in series with the TL-922's internal +110 volt power supply. The 600-ohm (two 300 ohm in series) resistor limits the relay coil cur-

*The price of the companion article is $2 delivered to any North American mailing address. For overseas delivery add $2. A supply of ≈ .1mm oxygen-free copper-foil, for making the RF connections to the vacuum-relays, and the #8-32 self-clinching nut, for the QSK-relay subassembly, is furnished with each article. For a retrofit-kit, to incorporate one of these circuit-improvements see page 124 of the December 1988 issue of *Ham Radio Magazine*.

rent to the correct ≈80 mA at 26 volts for each of the two 335-ohm relay coils in series and allows ≈55 volts to appear briefly across each relay coil at T = 0. This speeds up the make time of the relay. Both brands of relays had a measured make time of less than 2 mS with this circuit.

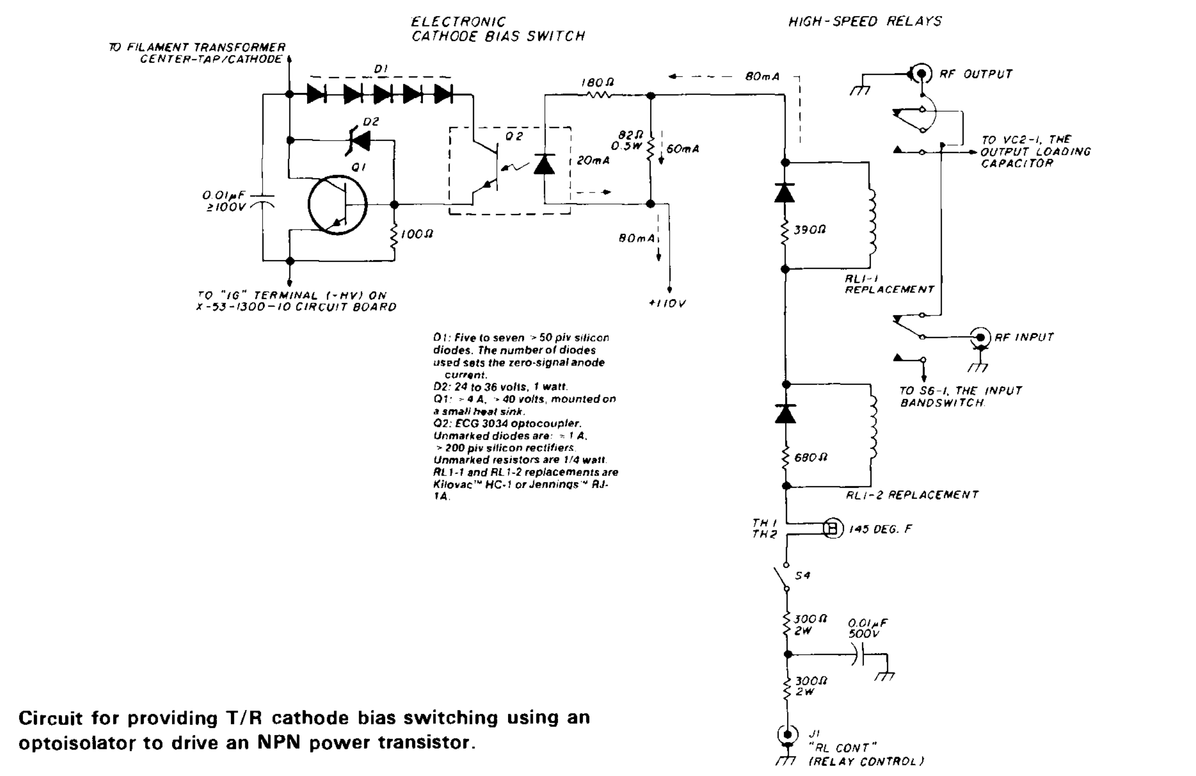
It's possible to control the break (release) time of a DC relay by the amount of external resistance placed in parallel with the relay coil. The external resistor is usually connected in series with a reverse diode so that the resistor doesn't act as a current burden during the on cycle. If the resistor is omitted (R ≈ inf), the coil voltage spike may rise to several hundred volts (reverse polarity) on break and the relay's break time will be very fast. The voltage spike is caused by the too-rapid collapse of the magnetic field in the relay coil (like the spark coil in a gasoline engine). The voltage spike isn't good for the insulation in the relay's coil or anything else in the circuit. This is why a reverse-connected diode is often placed in parallel with a DC relay's coil. The diode will also stretch the relay's break time considerably. In a full break-in application, a diode alone would provide too much break time, so a resistor is placed in series with each reverse diode to speed it up. When appropriate resistances are chosen, break times can be controlled accurately for correct break-time sequencing of two or more relays.

In **fig. 2**, the circuit diagram for this QSK circuit, the resistor on the output relay's coil has less resistance than the resistor on the input relay's coil. This keeps the output relay connected to the antenna slightly longer than the input relay can apply drive to the amplifier tubes, and assures that the output relay won't be opening (and arcing its contacts) before all of the drive power is removed.

An electronic cathode-bias switch replaces RL2-1 (the cathode-bias relay), D2 (the cathode-bias zener), R7, and C25. The new cathode-bias switch is an NPN power transistor, shown in **fig. 2**. The new circuit lets you adjust the zero-signal anode (plate) current in steps. The transmit bias voltage is adjustable in ≈0.8 volt steps. Normal transmit cathode bias is approximately +5 volts. During receive, +24 to +36 volts cuts off the 3-500Z's anode current.

An optocoupler drives the transistor switch. The optocoupler's resistor shunted input is connected in series with the relay control line. When current (80 mA) flows in the relay control line, 20 mA flows through the optocoupler's LED input and the optocoupler turns on.

FIGURE 2



Circuit for providing T/R cathode bias switching using an optoisolator to drive an NPN power transistor.

This activates the switch transistor, which turns on the 3-500Zs.

You can adjust the quiescent, or zero-signal, anode current of the 3-500Zs by shorting or unshorting the series diodes in the collector lead of the optocoupler. The correct SSB quiescent anode current is 160 to 200 mA. Lowering this current makes the tubes harder to drive and increases the IMD products. Too much current makes excessive heat and reduces efficiency.

Relay mounting and wiring

Mount the vacuum relays side by side on a rectangle of ≈ 14 gauge aluminum. Bolt a length of 12 mm × 12 mm aluminum right-angle stock to the bottom of the rectangle to form a mounting bracket. Press a self-clinching nut into a hole in the angle stock. Fasten the bracket to the top of the chassis with a screw passed through one of the mounting holes for the original relay.

To reduce acoustic noise, mount the relays without using the furnished hardware. To provide side clearance, make the relay mounting holes 2-3 mm larger than the threaded mounting shafts on the relays. Shock mount each relay with three "pillows" of silicone rubber. I prefer the red high-temperature General Electric Company silicone-rubber adhesive sealant.

It's important to have the relays positioned so that no metal-to-metal contact occurs between the relay and the aluminum mounting plate. If contact is made, there will be an acoustic path between the relay and the chassis of the amplifier — very much like the (sound) bridge on a violin — and the chassis will act as a sounding board. To keep the relays in the correct position while the silicone-rubber pillows are curing, cement* three cardboard rectangular spacers temporarily around each of the mounting holes for the relays.

Silcone rubber adheres well to most materials *if* the surface is prepared properly. I've found that the best surface-conditioning material is the silicone rubber itself. If the surface is greasy, clean it with a no-residue degreaser like TCE or Freon™ TF. Next, apply a dab of silicone rubber to a small, clean cloth and forcefully rub a thin film of silicone rubber onto all of the surfaces you want to bond together. (This information is not in the directions.) Apply the bonding silicone rubber immediately, before the conditioned surfaces start to cure. Add three dabs of silicone rubber before inserting each relay into a mounting hole. A small amount of silicone rubber will do the job; an excess will enhance the sound conduction to the mounting place. No silicone rubber should touch the cardboard strips because they'll be removed after curing. Now set the assembly aside for 48 to 72 hours of undisturbed curing. After curing, remove the cardboard strips.

* Stationery-store type rubber cement is suitable for this purpose.

Ground the metal bases of the relays electrically to the aluminum mounting plate. Do this by removing some of the paint from the relay bases and soldering a ≈ 14 mm long, 3 mm wide, flexible S-shaped strip of ≈0.1 mm copper foil to each relay and a ground lug to the mounting plate. The relay assembly must permit the relays to move in their holes slightly without touching the metal mounting plate.

Wiring the relays

The relay's coil terminals can break off easily with a sudden impact or too much stress. The wires that connect to these terminals should be flexible (no. 24 gauge stranded wire is satisfactory). Wire the RF terminals with 0.1-0.2 mm thick copper foil strips, 3 mm in width.

Don't use stiff wires to make a direct connection to the relay's RF terminals as this would provide a sound conduction path away from the relay. If you need to make a connection between an RF terminal and a stiff wire, solder a 3 mm × 20 mm flexible bridge of copper foil between the wire and the relay terminal. This will reduce sound conduction and stress on the relay.

All of this may sound like a lot of trouble, but the quiet that results is worth the effort.

Optimizing 10-meter bypass SWR

One frequently overlooked refinement in commercial amplifiers is apparent when the amplifier is switched off (bypassed), connected to a 50-ohm nonreactive load whose SWR = 1:1, and you find that the 10-meter input SWR to the amplifier is much worse than expected. This problem is caused by the inductive reactances in the T/R relays and their associated wiring. These inductive reactances can be canceled by connecting a capacitor (1-kV rating) of the proper value from the common terminal of the output relay to ground. Find the value of this capacitor experimentally by installing a 50-pF variable capacitor temporarily at the point in question. Adjust the capacitor until the 10-meter SWR is at a minimum when the amplifier is off. Do this with an accurate 50-ohm termination connected to the amplifier's output connector. Remove the capacitor and measure its capacitance on a capacity meter. Then permanently install a fixed capacitor of the closest standard value. In my amplifier it turned out to be 36 pF, 1 kV.

Odds and ends

- After you remove RL2, cover the hole in the chassis to maintain correct cooling air flow. With RL2 removed, the "ON THE AIR" lamp doesn't light on transmit. If this is important to you, it's possible to wire the lamp in series with the relay control line — provided that the value of one of the 300-ohm resistors is lowered to 240 ohms to offset the extra 6-volt drop in the lamp. You can control the lamp current by placing a resistor in parallel with the lamp.

• Prolong the life of the meter lamps either by increasing the resistance of the 10-ohm resistors that are in series with each lamp to 20-24 ohms, or by rewiring the circuits so that one 10-ohm resistor carries the current for each pair of meter lamps.

• If you own a TS-440 or TS-940 you may wish to eliminate the less-than-silent mechanical relay that operates the remote jack's (amplifier) relay control circuit. This relay can be replaced, *for positive voltage relay control switching only*, by an NPN switching transistor and two resistors. A schematic of this circuit is included (see **fig. 3**). The circuit will work on other makes of transceivers that use a mechanical relay for this job.*

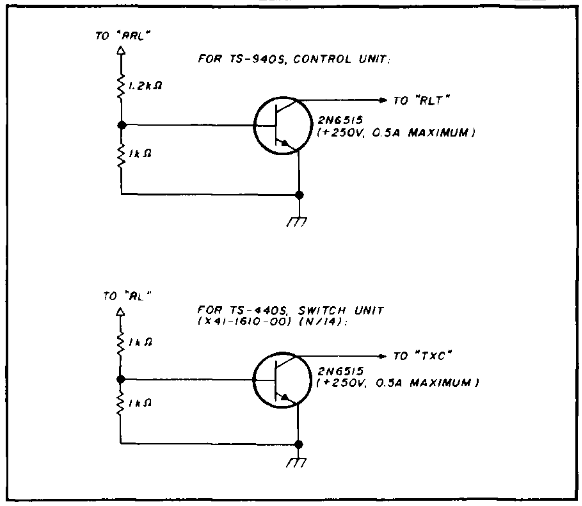
• You may have noticed that the full break-in circuit doesn't use a bypass capacitor directly across the TL-922's "RL CONT" (relay control) jack. There is a 300-ohm resistor between the bypass capacitor and the jack so that the switching relay or transistor in the transceiver isn't required to directly short out the bypass capacitor (which is charged to + 115 volts during receive). A direct short on a charged capacitor can easily create a nanosecond discharge current pulse of more than 100 A. In time, the pulse of current will erode the contacts of the transceiver relay that keys the "RL CONT" circuit. The current pulse can damage a 0.5-A switching transistor in short order. The 300-ohm resistor limits the peak switching current to less than 0.4 A.

• To tune up the TL-922 (or any grounded-grid amplifier) correctly, without using a two-tone generator and oscilloscope or a tuning pulser[1], follow these steps: Set the amplifier to the CW position, apply full CW drive power, and adjust the amplifier's tune and load controls alternately for maximum relative power output. The complete tune-up should take less than 10 seconds. The amplifier is now tuned up for CW or SSB operaion. The mode switch should be set to SSB for voice use.

Cost reduction

You can reduce the cost of the QSK conversion by about $80 if you use a less expensive high-speed relay to switch the 100-watt input circuit of the amplifier. The Trio-Kenwood TS-440S uses a Matsushita Electric Company high-speed, SPDT reed relay (Trio P/N: S51 1429 00) to switch the antenna circuit of the transceiver. This reed relay can handle 100 watts with ease, and the switching speed is probably under 1 mS — about twice

FIGURE 3



Solid-state relay switching circuits for use with the Kenwood TS940 and TS440.

as fast as the vacuum output relay. Take one important precaution: be sure that the reed relay doesn't apply drive power to the TL-922 before the output relay can connect the load to the amplifier. It may be necessary to add a make-delay circuit to the faster relay. *This relay is not suitable for switching the cathode bias.* Use it only with the electronic cathode-bias switch circuit. It's important to make sure that the reed relay has the correct 12 volts to operate the coil. The relay control current of 80 mA is far too much current for the reed relay's coil, so you must dump the extra current into a coil shunt resistor of the appropriate calculated value. The 600-ohm resistor in series with the relay contol line must be increased by 175 ohms to drop the added 14 volts (as the result of using a 12-volt coil in place of a 26-volt coil).

Use in other amplifiers

This QSK modification circuit will work in other amplifiers that use a + 110 Vdc relay power supply. I added QSK to a Heathkit SB-220 with this circuit. It works as well as the modified TL-922.

Parts suppliers

Vacuum-Relays: Surcom (Jennings), 619-438-4420. Ask for Lenk.
Kilovac, 805-684-4560. Ask for Gail. Either supplier will ship UPS/COD.

If you have any questions please write, or phone 805-482-3034. Most questions can be answered more accurately and promptly on the telephone than by letter.

References

1. R.L. Measures, AG6K, "Adjusting SSB Amplifiers," *Ham Radio*, September 1985, page 33.

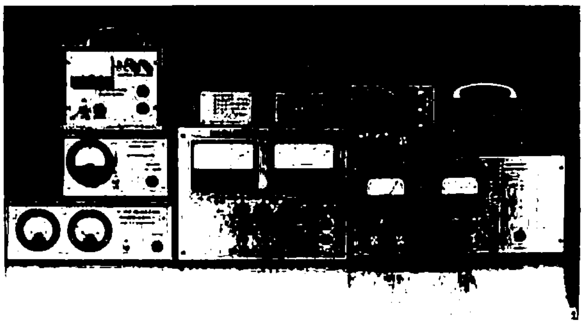
Article F **HAM RADIO**

* Many QSK-transceivers use a slow-acting, conventional relay to key the relay-control circuit from an external amplifier. The conventional relay in the transceiver causes a needless and often excessive time delay in the operation of the QSK relays in the amplifier. In some cases this delay may cause RF drive to be applied to the amplifier ***before*** the relays in the amplifier have had a chance to close. *The conventional, amplifier-keying relay in the transceiver should be replaced with a switching transistor circuit like the one shown in* **fig. 3**. This circuit requires a + 9 to + 12 volt, ≈ 10-mA signal on TX and ≈ 0 volts on RX. This voltage can be obtained from the point where the original ≈ 12 volt relay coil was connected in the transceiver circuit.

UNDERSTANDING AND USING 723 VOLTAGE REGULATORS

Simple circuits for chargers through test bench use

PHOTO A



All units use the 723 voltage regulator. Left—13.8 volt power supplies. Center—On top of the 28 A 13.8 volt power supply are two quick/trickle chargers. Right—On the bottom is a bench power supply. Above, battery charger (black meter) and to its right a 1.6 A 13.8 volt power supply.

I have read many articles on voltage regulation and power supplies and always learn something new from each one. I built my first-regulated, current limited power supply over 10 years ago. Since that time I have built quite an assortment of low-voltage dc power supplies. **Photo A** shows a few of them. In fact, not everything in the photo is a "power supply" — I'll explain that later.

Everything in photo **A** has one thing in common, the "723" voltage regulator (LM723CN, μa723CN, or equivalent number). It's adjustable from 2 to 37 volts, and has foldback current limiting. These features make it extremely versatile. This is basically an article on applications, but you'll still need an understanding of the circuit used with the 723 regulator (**fig.** 1).

basic components

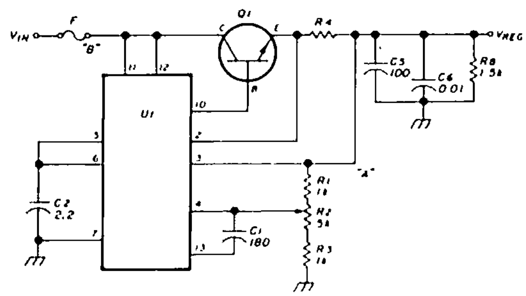
The projects focus on three items: R2, the voltage adjustment; R4, the current limit resistor; and Q1, the pass transistor. By varying these three things you can construct some interesting and useful equipment.

R2 is used to vary the voltage (**fig. 1**) from about 7 to 37 volts, less if V_{in} is less than 40 volts. (A different circuit for the 723 is required for voltages from 2 to 7 volts and will not be discussed here.)

R4 is a current limit resistor. The 723 regulator limits the flow of current through Q1 when it senses a voltage drop (on pins 2 and 3 of U1) of approximately 0.65 volts across R4. If R4 is 1 ohm, the current limit is 650 mA; 10 ohms for R4 gives a 65-mA current limit and 0.1 ohm gives a 6.5-A current limit.

Pass transistor, Q1 in **fig.** 1, handles the desired current load. Most sources rate the 723 regulator at 150 mA but I've seen it rated at 50 mA. Although the 723 regulator is protected by thermal shutdown, I've found that it can only stand a couple of shutdowns before failure. Because most of the uses for the 723 regulator require more than 150 mA, the pass transistor or multiple-pass transistors are used to handle the desired maximum current. My experience shows that the 723 regulator likes loads well under 50 mA.

FIGURE 1

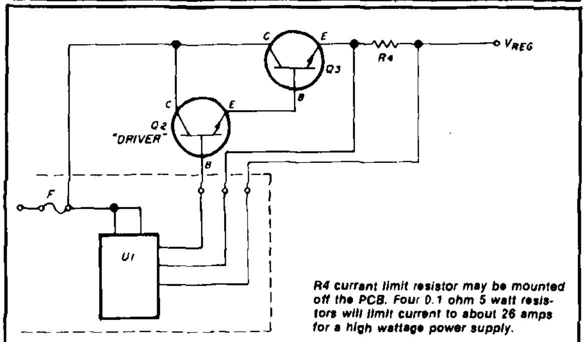


Basic 723 regulator circuit with pass transistor is adjustable from about 8 volts to 30 volts with appropriate V_{in}.

The 2N3055 in a TO-3 case is a good choice for the pass transistor. It is an inexpensive power transistor rated at 15-A and 115-watts dissipation. I never push the 15-A rating but would rather use several pass tran-

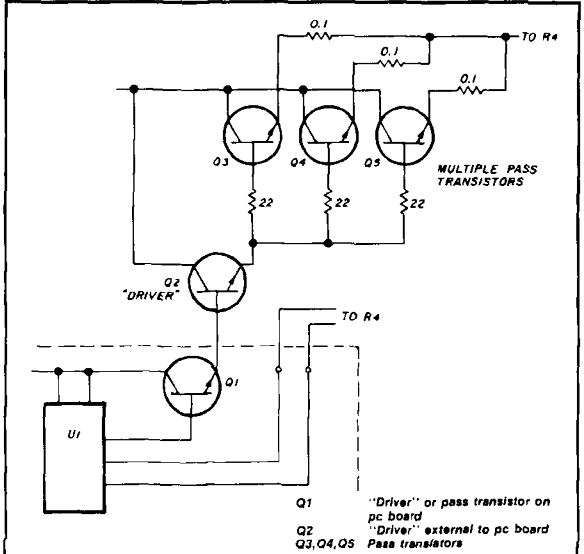
By W.C. Cloninger, Jr., K3OF, 4409 Buckthorn Court, Rockville, Maryland 20853

FIGURE 2



Use of "Darlington pair" (Q2, and Q3) for pass transistor reduces load on the 723 regulator.

FIGURE 3



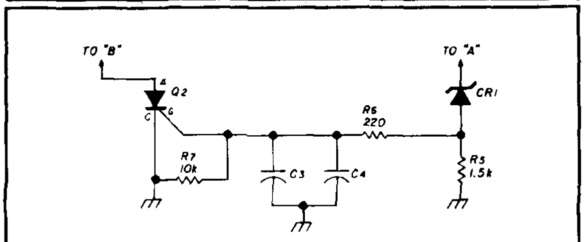
Multiple pass transistors (Q3, Q4, and Q5) with load balancing emitter resistors for high amp applications.

sistors in parallel and let each one handle about 5 or 6 A. You must also consider power dissipation, and adequate heat sinking is required. A single 2N3055 for Q1 requires about 17-mA drive for a 0.5-A output and about 100-mA drive for a 2-A load on Q1. As you can see, the 723 regulator's output capacity can be quickly exceeded just to drive a single-pass transistor.

safely loading the regulator

A good way to handle the required drive to the pass transistor without overloading the 723 regulator is to use a "Darlington pair". **Figure 2** shows Q2 and Q3 in a Darlington configuration. Q2 is the driver for Q3. I didn't show a Q1 in this diagram because I want you to think of Q1 as being mounted on the voltage regu-

FIGURE 4



Typical "crowbar" overvoltage protection circuit using a zener diode for voltage reference.

parts list

C1	*100 to 500 pF*
C2	*2.2 μF tantalum*
C3,C4	*0.05 to 10 μF*
C5	*100 μF*
C6	*0.01 μF*
CR1	*15 v 1 watt zener diode*
Q1	*2N3055*
Q2	*SCR to suit current wax*
R1,R3,R5	*1k ohms*
R2	*5k potentionmeter*
R6	*220 ohms*
R7	*10k ohms*
R8	*1.5k ohms 1 watt*
U1	*LM723CN regulator*
R4	*Current limit resistor 0.1 ohm 5 watt wire wound for 6.5 A limit; 10 ohms for 65 mA limit.*

C3 and C4 are only used if needed to eliminate triggering of SCR by transients, use minimum value possible.

lator circuit board. With the high gain of the Darlington pair, the drive to Q2 from the 723 regulator is only 0.7 mA for a 2-A load and 1.5 mA for a 3-A load. The 723 regulator is now barely loafing.

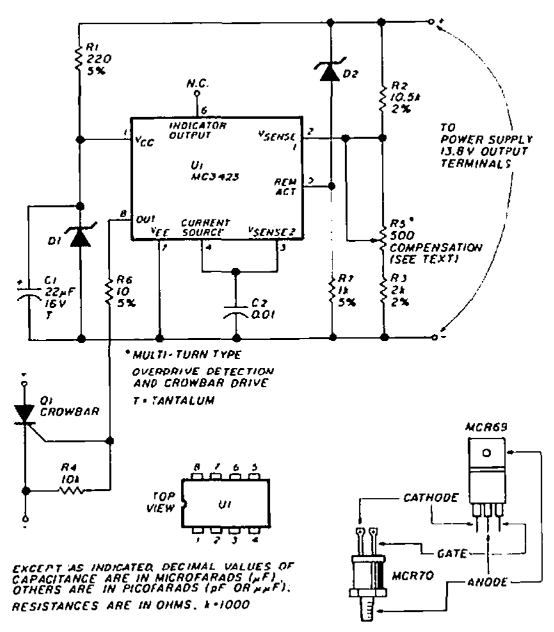
Now let's look at a "super duty" current, maybe 30 A. **Figure 3** shows a circuit with two drivers and three or more pass transistors (Q3, Q4, and Q5). The 0.1-ohm 5-watt emitter resistors are important because they make the multiple pass transistors share the load. The 22-ohm resistor attached to the base of each pass transistor also helps equalize load, but these resistors are not absolutely necessary.

Another important design feature is the overvoltage protection or "crowbar". A crowbar is typically a circuit which detects voltage exceeding a fixed value and fires an SCR to short circuit the input supply to the regulator circuit and blow a fuse. The term crowbar probably comes from the use of brute force to blow

the fuse and stop the overvoltage condition. Don't try to blow a 35-A fuse with a 6-A SCR!

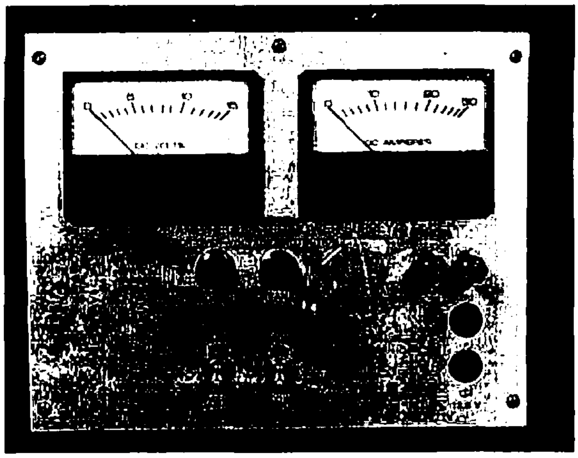
A common crowbar circuit is shown in **fig. 4**. Capacitors C3 and C4 help prevent false triggering of the SCR by transients and spikes. But it's really not false triggering at all; the crowbar is doing exactly what it is supposed to do. If you connect an oscilloscope to the output of your power supply and turn the power switch off and on a few times, I think you may be surprised at the spikes. These spikes are a real nuisance and can be very difficult to suppress.

FIGURE 5



Overvoltage circuit[1] using the MC3423 overvoltage sensor.

PHOTO B



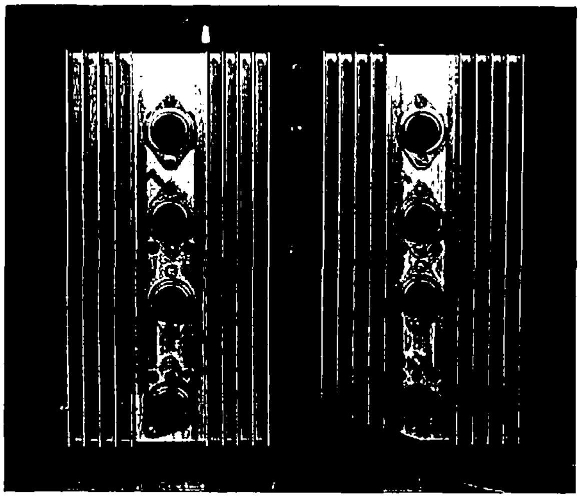
28-A power supply. Note switch for 2-speed fan.

An excellent article on overvoltage protection using an MC3423 overvoltage sensor specifically designed to fire a crowbar was written by VK5IK.[1] The MC3423 circuit is shown in **fig. 5**.

Photo A shows two mini-boxes on top of the 28-A power supply. These are battery chargers for an HT. The box with the black-faced meter is a NiCd battery charger with two outputs — one with adjustable current and one with fixed output. The bench supply on the lower right has both adjustable voltage and current capability.

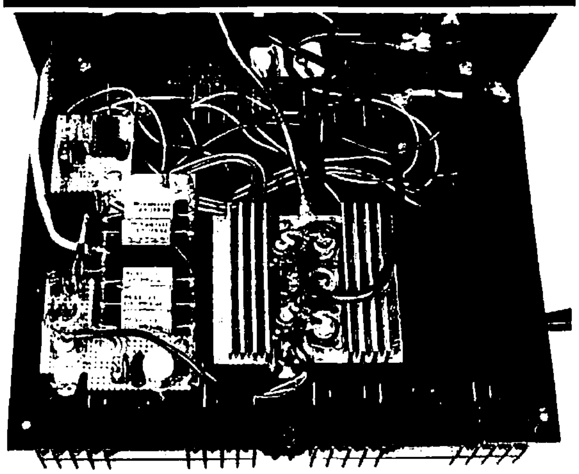
Let's take a closer look at how the 723 voltage regulator is used in some of this equipment. The high ampere power supply in **photos B, C,** and **D** was used

PHOTO C



Back of 28-A power supply. The "driver" is the transistor at the lower left. At the lower right is a 35-A fuse holder. The other six transistors are 2N3055 pass transistors.

PHOTO D

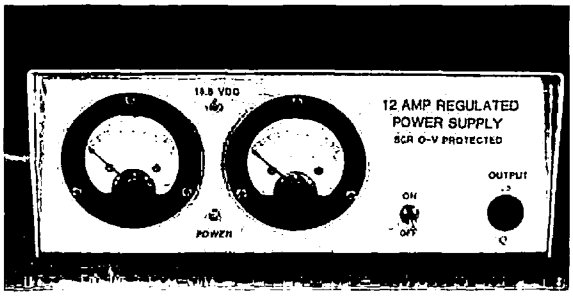


28-A power supply wiring. Voltage regulator board is at upper left. The crowbar is on the separate board at the lower left. Note the five 0.1 ohm 5 watt current limit resistors soldered to the two buss wires.

for several years with my TR7A and several Atlas transceivers. You can keep a two-speed fan on low for any current under 10 A continuous and all SSB operation. The heat-sinked full-wave bridge at the lower right of **photo D** comes from diodes "liberated" from the horseshoe rectifier assembly of a 65-A automotive alternator. These rectifier assemblies contain six diodes and usually only one fails.

My latest power supply is shown in **photo E**. The meters were hamfest specials, both 0-1 mA with shunt or series resistors as needed. This is the first time I have made and used a pc board. I "married" the VK5IK overvoltage circuit to my 723 circuit. To reduce unwanted triggering of the SCR, I found it necessary to increase C2 of the VK5IK circuit to 0.047 μF.

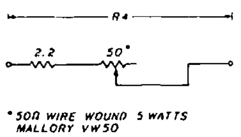
PHOTO E



12 A power supply with "matched" meters for 0-20v and 0-10 A.

The two-output battery charger in **photo A** (box with black meter) uses two separate 723 circuits from the same dc input source. The fixed output is limited by R4 to 15 mA to trickle charge AA NiCds. The voltage is set to perhaps 24 volts, plenty for a dozen or more AA cells at a time. Because the current limit is fixed, it doesn't matter whether one or a dozen AA cells are on trickle charge; no adjustment is necessary. I did place an LED in this output to show when current is flowing — this eliminates the need for a meter.

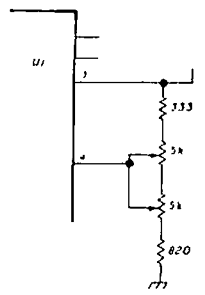
FIGURE 6



Current limit resistor schematic for adjustable current limit of about 10 mA to 1 A.

The second output is current adjustable from about 12 mA to 300 mA by the use of a fixed resistor in series with a potentiometer (**fig. 6**). Again the voltage is set high enough to charge a large number of cells at one time. The charge rate remains constant until you change the adjustment.

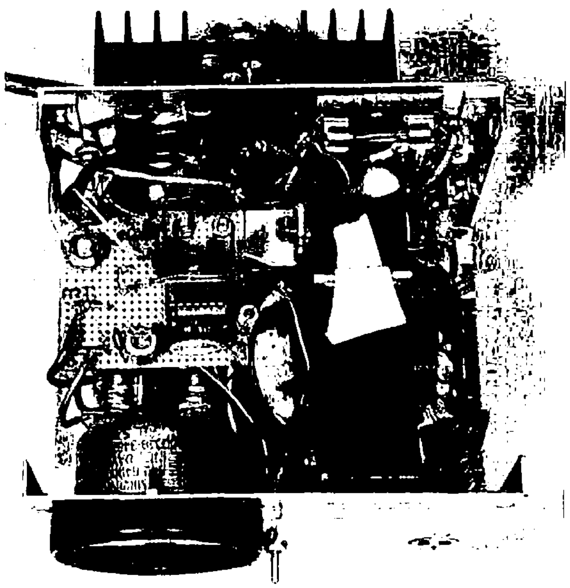
FIGURE 7



Two potentiometers provided little benefit to reduce minimum voltage since the lower voltage limit is 7 volts with the 723 circuit used.

The 0 to 1-A bench supply shown at the lower right in **photo A** is another variation of the battery charger described above, with R2 mounted on the front panel for convenient voltage adjustment. (Well, that's almost how I did it!) I found that the minimum voltage adjustment using the 5k pot with the 1k resistors (R1 and R3) was just under 8 volts. I tried to get the lowest possible voltage and changed R1, R2, and R3 as shown in **fig. 7**. The change didn't do everything I wanted (remember the circuit used for the 723 has a lower limit of 7 volts), but because I had already added the second potentiometer to the panel I didn't change it. Replacing the 2.2-ohm resistor in **fig. 6** with a 0.65-ohm 1-watt resistor (actually a couple of resistors in

PHOTO F

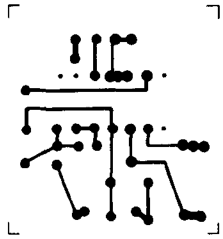


Battery charger for HT uses voltage doubler on left half with 723 circuit on right half.

(continued on page 51)

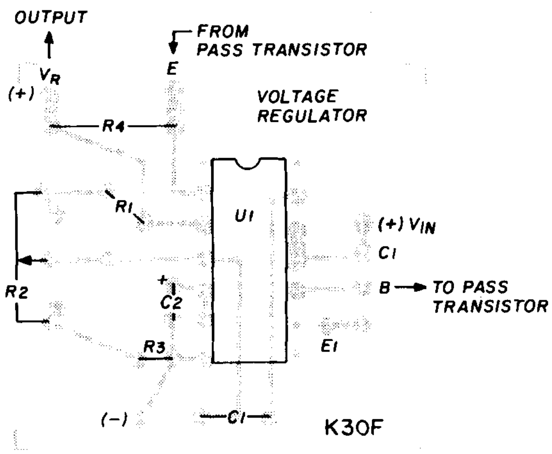
(continued from page 46)

FIGURE 8



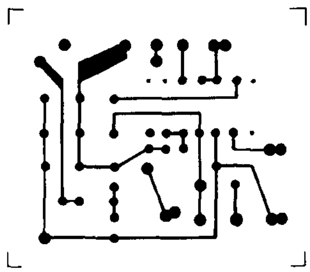
Foil side of the basic 723 regulator PC board (actual size).

FIGURE 9



Component side of the basic 723 regulator PCB showing component location (enlarged view).

FIGURE 10

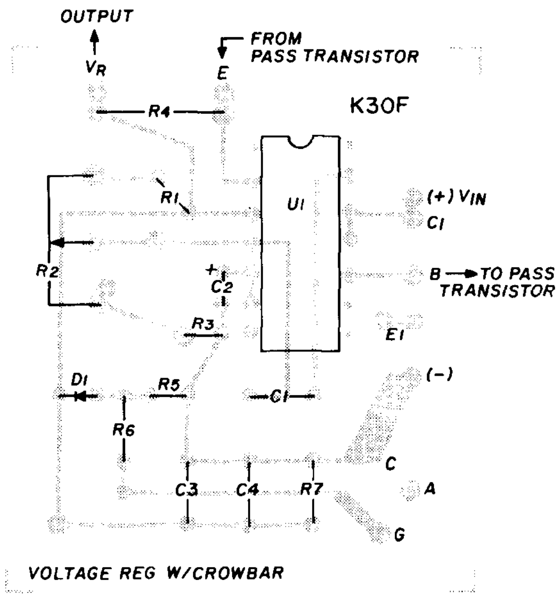


Foil side of the 723 regulator PCB with "crowbar" circuit added (actual size).

parallel) allowed me to attain the 1-A current limit. I use this bench supply primarily as a battery charger.

I then made a battery charger for an HT (**photo F**) which will both quick and trickle charge. I selected R4 to limit the current to 150 mA (I have also used 450-

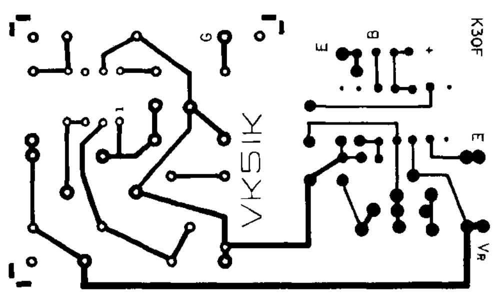
FIGURE 11



Component side of the 723 regulator PCB with "crowbar" showing component placement (enlarged view).

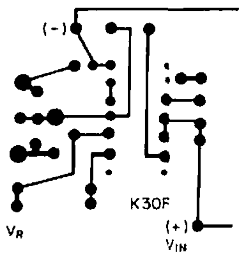
mA limit). I adjust the voltage with a fully charged battery pack and a milliammeter in the circuit so that the charger will float across the battery pack at 15 mA. I even keep the charger connected while using the HT. The quick charge is not quite as good as more sophisticated circuits which maintain a maximum rate until a set point and then switch to the low rate. The 723 circuit starts out at maximum charge but tapers off as the voltage of the battery pack increases with the level of charge. The quick charge is effective to about 60 percent of full charge before it passes through a normal rate and finally to the 15 mA trickle rate. It's not

FIGURE 12



Foil side of the basic 723 regulator circuit "married" to the VK5IK overvoltage protection circuit (actual size).

FIGURE 13



Foil side of multiple 723 regulator circuits for multiple voltages and/or current limits (actual size).

fancy but it sure beats the charger supplied with the HT.

The charger in **photo F** has a voltage doubler. It was originally built to use with a TR2400 with an 8-cell battery pack. I used the charger in the car, but found that the car's electrical system voltage wasn't high enough to charge the HT battery pack unless the motor was running and the car's voltage was about 14.1 volts. I added the voltage doubler circuit[2] and it solved the charge problem. But this little device puts out a lot of RFI. It seems to be a broad-banded frequency sweeping RFI on any hf frequency. I'm not sure how it would work if enclosed in a shielded minibox.

I built another HT battery charger without the voltage doubler for use in the shack. I now have an HT with a 7-cell battery pack so I can use the car's electrical system, a 13.8-volt power supply, or a wall-type dc module.

I have included several circuit board designs. **Figure 8** is the basic 723 voltage regulator circuit. The component side is shown in **fig. 9**. The pc board has provision for the on-board driver. If the driver is mounted on the board, E1 (not B) goes to the base of the pass transistor or the second driver. The collector voltage to the on-board drive is supplied by C1. The same pc board is shown in **fig. 10** with a conventional crowbar circuit added; **figure 11** shows the component side. A 4 to 6-A SCR can be mounted directly on the board, but SCRs for higher current applications should be mounted remotely (no heat sink required) and R7 connected directly to the SCR.

Figure 12 shows the 723 circuit "married" to the VK5IK circuit. **Figure 13** has multiple 723 circuits from a common supply so you can have multiple outputs and charge NiCds or gel-cells from the same supply simultaneously.

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Article G HAM RADIO

THE WEEKENDER

DTMF group call decoder

With frequency congestion becoming a problem in certain areas, the use of selective decoders is increasingly popular and in some places very nearly a necessity. Although some manufacturers include these devices in their new equipment, many hams use older equipment not yet ready for retirement.

Circuit description: Power supply

DC voltage enters through L1, which is used to filter power supply noise. Regulator Q1 steps down the voltage to the required +5 Vdc. The voltage is then filtered by C1 and C2. (See **fig. 1** for the complete circuit.)

DTMF decoder

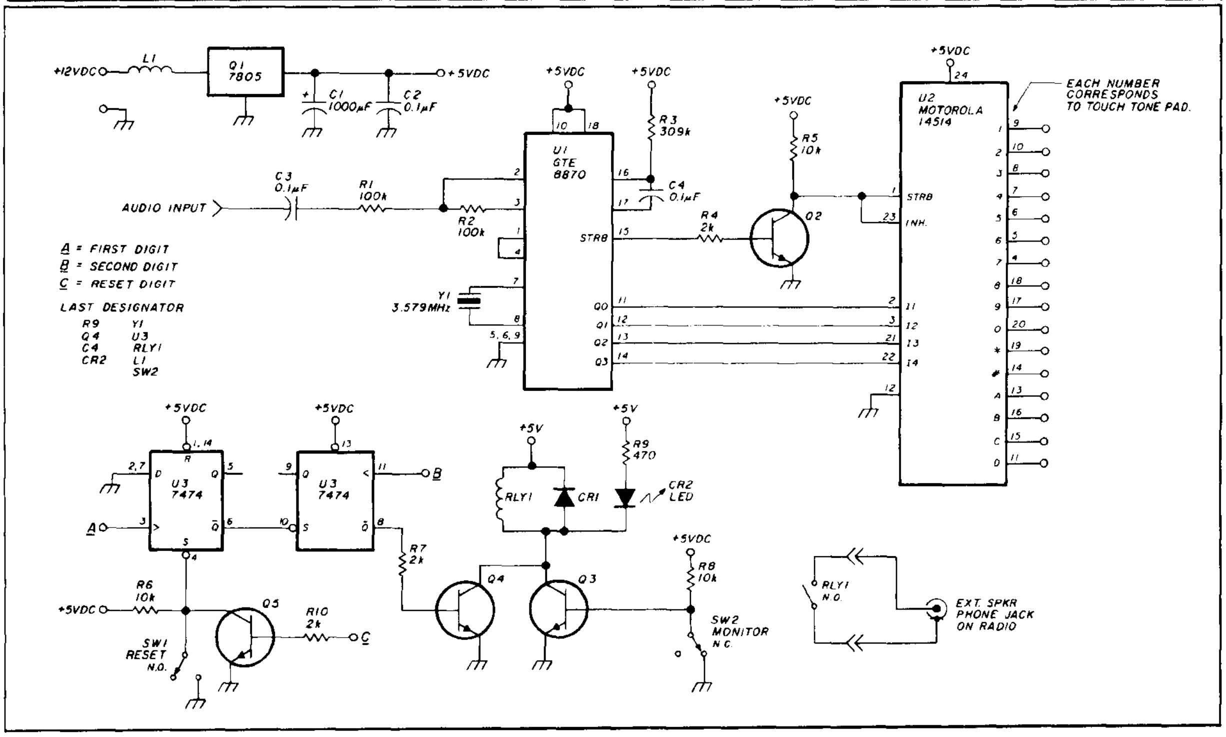
The audio tone signal enters through C3 to the summing amplifier in U1. Network R3 and C4 determine valid tone detection time. A positive-going strobe pulse is presented on pin 15 every time a valid DTMF code is received. Components R4, R5, and Q2 invert this signal designation to U2, indicating that the 4-bit decoded signal is present on Q0 through Q3.

4 to 16 multiplexer

After U2 receives a strobe from U1, it takes the code and puts a high-going pulse on the decoded output. If you use a 4×4 DTMF keypad, all 16 outputs are active. If you choose a 3×4 keypad, only outputs 1-0, *, and # are active.

By Roger Owens, AA4NX, 2042 Old Big Cove Road, Owens Cross Roads, Alabama 35763

FIGURE 1



Schematic of the DTMF decoder and related circuitry.

PARTS LIST

C1	1000µF 35 volt	Electrolytic cap
C2,C3,C4	0.1µF 50 volt	CER capacitor
CR1	IN4148	General purpose diode
CR2	TI3/4	LED green
L1	(as needed)	Inductor
Q1	7805	+5 volt regulator
Q2-4	2N3904	NPN transistor
R1,R2	100 k	1/8 watt 1 percent
R3	309 k	1/8 watt 1 percent
R4,R7	2 k	1/8 watt 1 percent
R5,R6,R8	10 k	1/8 watt 1 percent
R9	470 ohm	1/8 watt 1 percent
RLY1	IA05	+5 volt relay
SW1	Normally open	Push button-momentary
SW2	Normally closed	Push button-momentary
U1	GTE 8870	DTMF decoder
U2	Motorola MC14514A	4 to 16 decoder
U3	74LS74	D type flip-flop
Y1	3.57 MHz	Color burst crystal

Decoder

There are two inputs applied to U3 — A and B. Input A is connected to the U2 decoded output used for the first digit. Conversely, input B is connected for the second decoded digit.

Once input A receives a positive going pulse, U3 pin 6 goes high allowing input B to be accepted; this is the second decode digit. U3 is arranged so the 2-digit signal must be entered in the correct sequence.

Once this is done a signal is applied through R7 to the base of Q4, turning it on, pulling in relay 1, and closing the audio path. Diode CR1 protects the circuit from relay 1 CEMF.

When Q4 turns on, LED CR2 comes on indicating reception of a valid sequence. Resistor R9 limits the current through CR2 to about 10 mA.

Reset

Once the relay is closed by a valid sequence, it's deactivated by pushing the reset button or by connecting input C to a selected decoded output. Either of these resets pulls U3 (SET) low causing relay 1 to open, breaking the audio path.

Monitor

If you wish to monitor the frequency, open the monitor switch. This lets Q3 turn on closing relay 1. Closing this switch squelches the audio again.

Ordering information

You can order printed circuit boards for $15.00 each from: Valley Communications, P.O. Box 277, Owens Cross Roads, Alabama 35763.

Article H **HAM RADIO**

ELECTRO-BRAILLE TRANSDUCERS
AND THEIR APPLICATION

By G. W. Horn, I4MK, 17, via Pio IX, 40017 S. Giovanni Persiceto, Bologna, Italy

Almost all digital read-out devices rely on the user's eyesight. LEDs, LCDs, and other digital displays are useless to blind operators. Acquiring data in a usable form is an obstacle that has plagued the sightless ham since the earliest days of wireless.

It's true that digital data (from a DVM or a counter, for instance) may be "spoken" by a voice synthesizer, but such designs are often cumbersome to use. Data can also be "written" on a row of tactile sensors coded in Braille. The second solution is better because the displayed data is "frozen" into the tactile sensors to be read and reread at will, without the uncertainty of synthetic speech. Written information is usually more precise and immediate than spoken.

Because many blind people read Braille, a read-out device that converts electrical voltages to a mechanical Braille format seemed ideal to me.

For those not familiar with the system, Braille characters are formed on a six-dot matrix (see **fig. 1**). The presence or absence of an embossed dot at each of the six crosspoints determines the "value" or meaning of that character. These dots are conventionally called P1, P2, P3, P4, P5, and P6. The figures from 0 to 9 are represented by points P1, P2, P4, and P5; the sign is given by the four points P2, P3, P5, and P6; and the letters are made by combinations of all six points. If you assign a bit sequence (dot = 1, no dot = 0) to the six dots, you can consider Braille a true digital code.

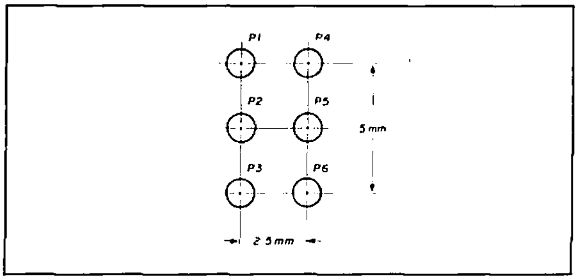
You can convert alphanumeric information of digital origin into Braille using "tactile" or electro-Braille transducers. There are two main types:

- **Vibrating.** These tranducers consist of thin piezoceramic reeds, like those of some reading machines. Among these are the optacon.[1,2]
- **Electromechanical** on/off. These are usually employed in telephone exchanges attended by blind operators.

Electromechanical transducers have six pins arranged according to the standard Braille pattern shown in **fig. 1**. The pins are raised from the "no dot" level (0) to the "dot" level (1) by means of suction solenoids. They can be classified by operating mode as mono- or bistable electro-Braille *transducers.*

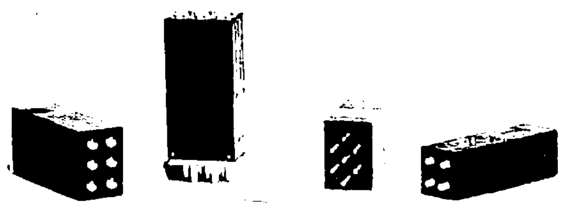
The pins of the monostable transducer (the simplest to construct) in **photo A** go up when the related solenoids are energized and remain up until enough current flows into the solenoids. There is a problem, however. The lack of a mechanical latch means that the pin raised at logical 1 can be pushed down by fingertip pressure. A further drawback is the dimension of

FIGURE 1



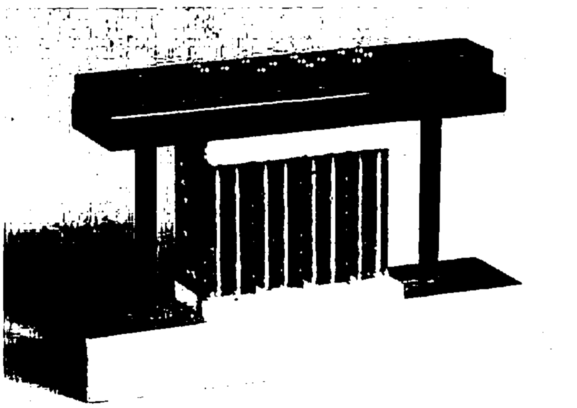
Standard Braille matrix.

PHOTO A



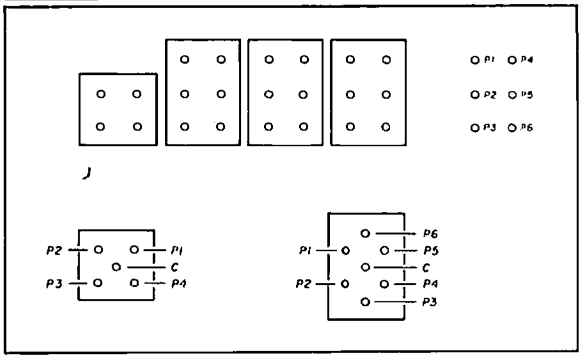
Four and six-dot monostable electro-Braille transducers (manufactured by Tiflotell.

PHOTO B



Bistable electro-Braille transducers arranged in a row of four (manufactured by Tiflotel).

FIGURE 2



Reading row of three monostable and one polarity transducer.

this transducer's matrix; it's slightly larger than standard Braille.

The bistable transducer in photo B has a mechanism that latches the pin into the position where the control pulse has driven it previously. Consequently, a pin is raised at 1 when a short current pulse is applied to its solenoid. A similar pulse of opposite polarity will bring it to 0 again.[3,4]

In another version, each pin is driven by two independent solenoids — one for raising (write), and a second for lowering (erase). Both are controlled by pulses of the same polarity.

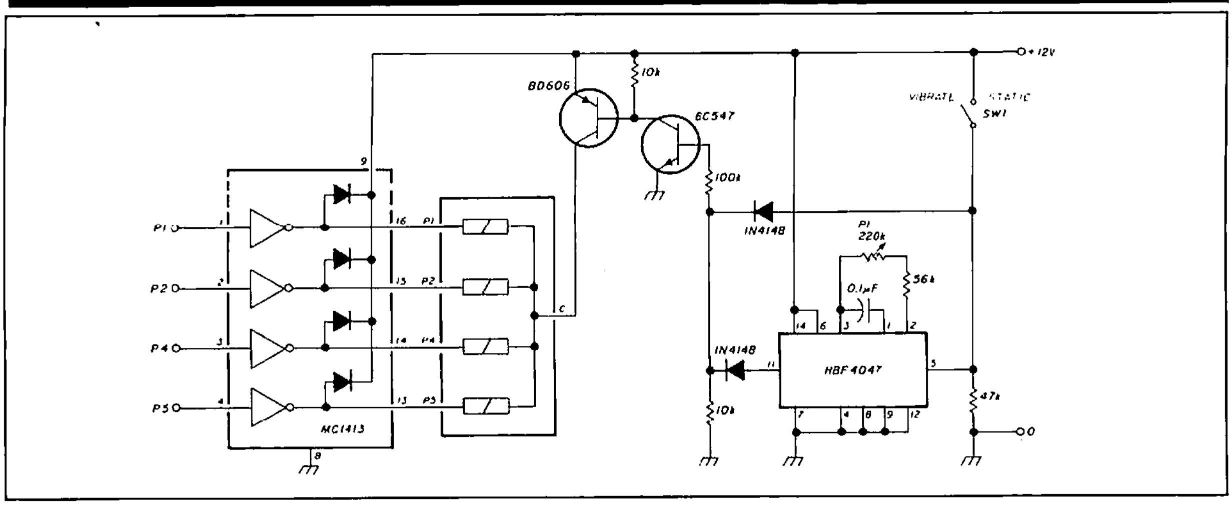
The main advantage of the bistable transducer is that the pin, once at 1, can't recede under fingertip pressure because of the mechanical latch. Another advantage is that the transducer is pulse energized. Power drain and consequent heating are also reduced to a minimum in this device. Bistable transducers, whose matrices reproduce Braille's dimensions exactly, are generally assembled into a block or row of four (or $n \times 4$).

Because of their dissimilar internal structures, mono- and bistable transducers need different kinds of electrical drive — static (DC) and dynamic (pulses).

The typical monostable transducer (shown in photo A), drains about 50 mA per pin at +12 volts. The peripheral driver array MC 1413 (ULN 2003) is a suitable driver for its four or six pins. The seven Darlington pairs of this chip can supply the required current and are intrinsically protected against inductive voltage spikes.

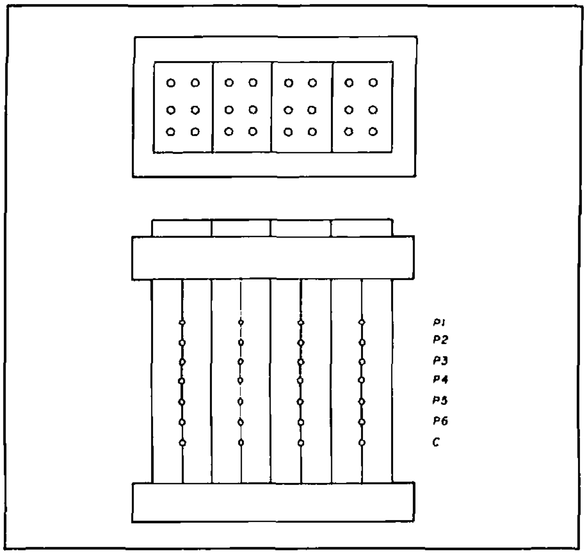
Translation of the BCD data coming from a three-digit DVM (a CA 3162E, for instance) into Braille requires a row of three-figure and one-polarity trans-

FIGURE 3



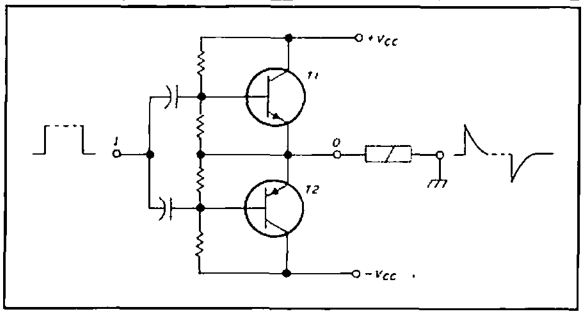
Vibrating-mode drive of four-dot monostable transducers. Vibration frequency is controlled by P1.

FIGURE 4



Reading row of four bistable two-phase electro-Braille transducers.

FIGURE 5



Low output impedance differentiating driver.

ducers (see **fig. 2**). If you use monostable transducers, remember that Braille numerals consist of four dots (at maximum), the operational signs have three dots, and the decimal point (DP) is conventionally indicated by point P3 of *each* transducer. This means there are a total of 18 solenoids to be driven (at a maximum DC current of approximately 1 A), requiring three ULN 2003 driver ICs.

Power drain and heating can be reduced considerably by supplying the transducer row with a square wave (see **fig. 3**) instead of a DC current, which lets the pins vibrate. The resulting sensation makes reading easier and relieves the uncertainties caused by the tendency of the pins to recede under fingertip pressure.

The bistable transducer's solenoids (shown in **photo B**) are controlled by short two-phase pulses.

A +12 volt, 20-mS pulse makes the pin rise at logical 1; another −12 volt, 10-mS pulse resets it to logical 0 (coil resistance 65 ohms, inductance 15 mH). **Figure 4** shows schematically a reading row of four of these types of transducers.

Control pulses are delivered to the solenoid by a low impedance driver capable of supplying enough current in both directions. It may consist of a couple of complementary transistors arranged in a mirror emitter-follower configuration (see **fig. 5**). This can be implemented with a single dual NPN/PNP transistor like the BFX 79.

The data to be read should be saved into suitable registers, independent from transducer's type and accompanying driver circuit. The input data from a DVM, for example, is mostly multiplexed. A quad-latch register, like the MC 14042, may be used in this instance (see **fig. 6**).

If the transducers are monostable, their driving Darlington will be controlled directly by the Q's of their respective latches. If they are bistable, the Q outputs must be differentiated to get to a positive driving pulse at their rise to 1, and to a negative one at their fall to 0.

Because transducer reading occurs in Braille, the information brought into the relevant register must be translated correspondingly. In the case of BCD data coming from DVM, DMM, ADC, and counters, the Braille translation must be made according to **table 1**.

The fundamental difference between the two codes is that in Braille, contrary to BCD, 0 isn't represented by a sequence of all-null bits. A Braille 0000 sequence would be meaningless indeed!

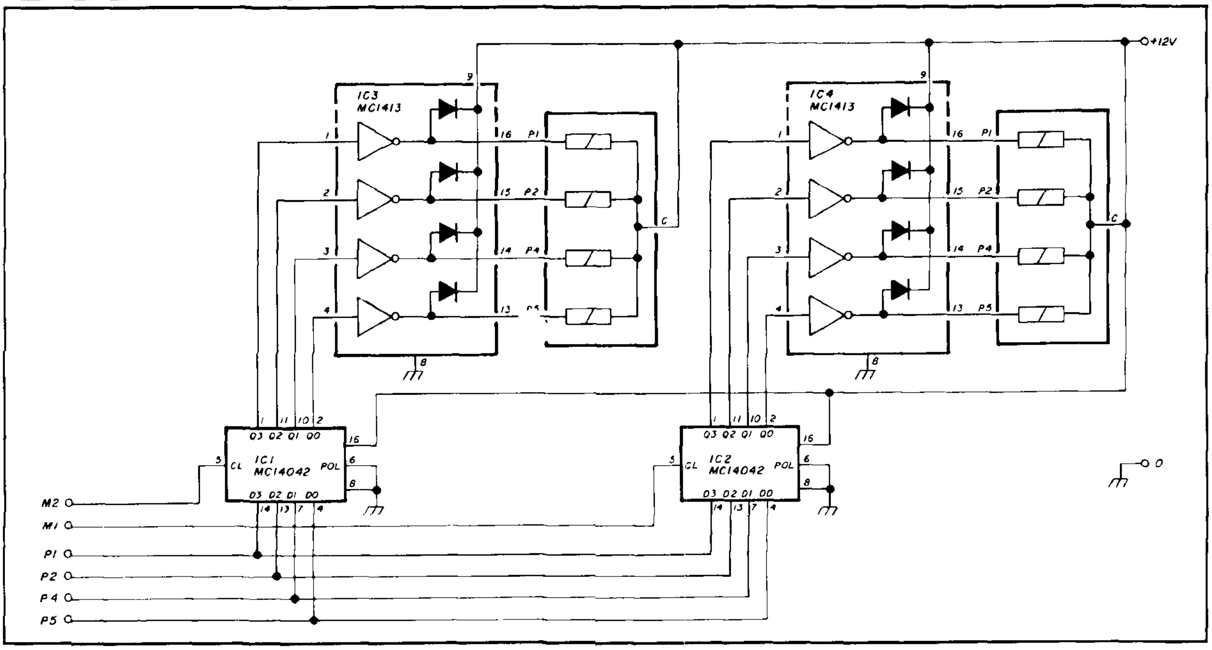
Code conversion can be done by splitting the relevant process into two phases: BCD-to-decimal and decimal-to-Braille conversion. The only BCD-to-decimal decoder that can be used in this way is the MC 14028 which, compared with the more common 4028, doesn't decode the invalid sequences. This feature is of paramount importance when data to be translated into Braille are delivered by a DVM like the CA 3162E. Overflow, polarity reverse, and other situations are given by bit combinations corresponding to

TABLE 1

Braille translation

N	BCD				Braille					
	D	C	B	A	P1	P2	P3	P4	P5	P6
0	0	0	0	0	0	1	0	1	1	0
1	0	0	0	1	1	0	0	0	0	0
2	0	0	1	0	1	1	0	0	0	0
3	0	0	1	1	1	0	0	1	0	0
4	0	1	0	0	1	0	0	1	1	0
5	0	1	0	1	1	0	0	0	1	0
6	0	1	1	0	1	1	0	1	0	0
7	0	1	1	1	1	1	0	1	1	0
8	1	0	0	0	0	1	0	1	1	0
9	1	0	0	1	1	1	0	1	0	0
+	–				0	1	0	1	1	0
–	–				0	1	1	0	0	0

FIGURE 6



Multiplexed two-digit Braille data stored in quad latches provides control of the two four-dot monostable transducers.

binary figures greater than 9 which, if decoded, would give rise to completely inaccurate numerical indications. Once in decimal, the figure has to be translated into Braille. This can done using the diode matrix shown in **fig. 7**.

It's worth noting that, due to the data structure of many modern digital XCVRs, the actual data is provided in seven-segment *format* rather than in BCD. In this case, the BCD-to-Braille converter must be preceded by a seven segments-to-BCD one. Such a conversion can be performed[5,6] by the logic shown in **fig. 8**. Inputs coming from segments a, d, e, f, and g are enough. However, the decimal outputs (except N = 0) must be cross wired in order to preserve the correct correspondence between input and output data.

The electro-Braille transducers may be used to read the DVM. **Figure** 9 shows a DVM circuit suitable for driving the reading row. One peculiarity of the circuit is the way it generates multiplex pulses M2, M1, and M0. The three AND gates, together with the relevant RC groups, "shape" the pulses in order to suppress spurious signals which would incorrectly trigger the registers.

The TTL digital data delivered by the CA 3162E is then translated by IC3 and IC4 (MC 14504) at MOS level. This is necessary because, to be controlled, the bistable transducers chosen need ±12 volt pulses.

As shown in **fig. 10**, reading row control is performed by three quad latches (MC 14042), followed by three quad-differentiating drivers (DR2, DR1, DR0) which drive the P1, P2, P4, and P5 pins of the figure transducers. The fifth, or quint-differentiating driver (DR ±, DP), controls the P2 P5 (sign −), P2 P3 P5 (sign +) pins of the polarity transducer, and the P3 pins (decimal point DP) of the three-figure ones.

The electrical circuit of the differentiating drivers (DR) is shown in **fig. 11**. The drivers have been simplified without compromising their functionality.

The transducer's driving circuit (**fig. 10**) is controlled by the DVM's output through the BCD-to-Braille converter of **fig. 7**. The differentiating drivers (DR/DP), *related to the decimal point* (DP) P3 pins, are controlled by the range selector located in the DVM's front-end unit. The polarity information is obtained from a separate logic (**fig. 12**) made of a dual four-input NAND (IC1) and a dual four-input NOR (IC2) gate. IC1 decodes the 1100 sequence which, corresponding to the M1 multiplexing pulse, indicates that the polarity of Vx at DVM's input was reversed. IC2 detects the 0000 sequence that occurs when Vx = 0. The following are possible situations:

Vx = 0 figure transducers indicate 000 (in Braille 0111 0111 0111)
polarity transducer: no dot

0 < Vx < 0.999V figure transducers indicate Vx three-digit value
polarity transducer: +

−0.099V < Vx < 0 figure transducers indicate Vx three-digit value polarity transducers: −

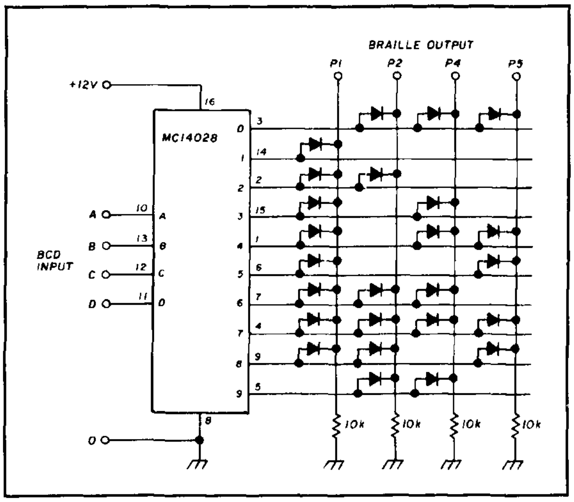
Vx > 0.999V figure transducers: no dot
polarity transducer: +

Vx < −0.099V figure transducer: no dot
polarity transducer: −

Note: The CA 3162E accepts a maximum positive input voltage of 0.999 volts and a maximum negative one of 0.099 volts.

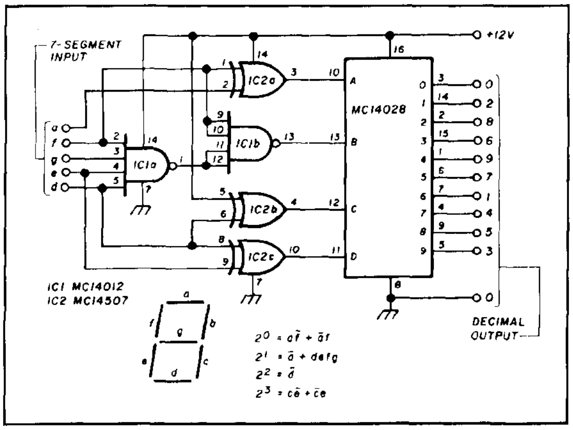
To turn the DVM into a true DMM (**photo C**), you need a front-end unit. **Figure 13** shows a circuit that you can use. It allows measurements of AC/DC voltages and currents, as well as resistances in the following ranges: 100 mV to 1 kV, 100 μA to 1 A, 100 ohm to 1 megohm.

FIGURE 7



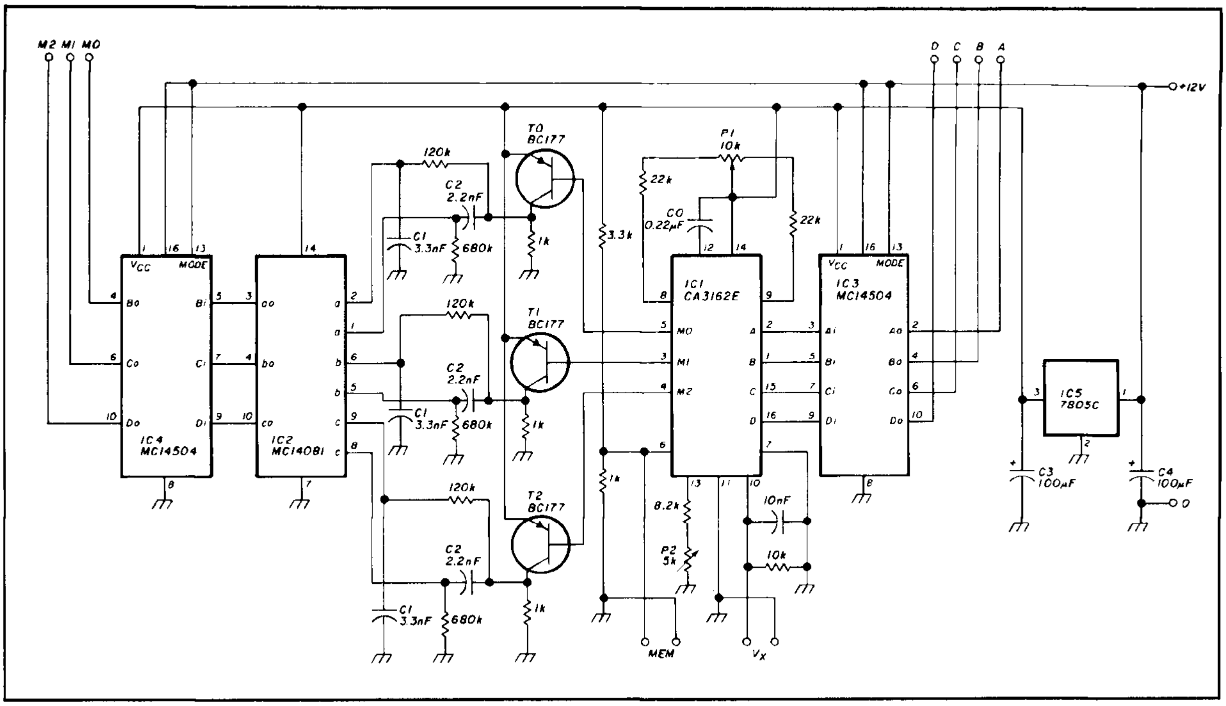
BCD-to-Braille data converter.

FIGURE 8



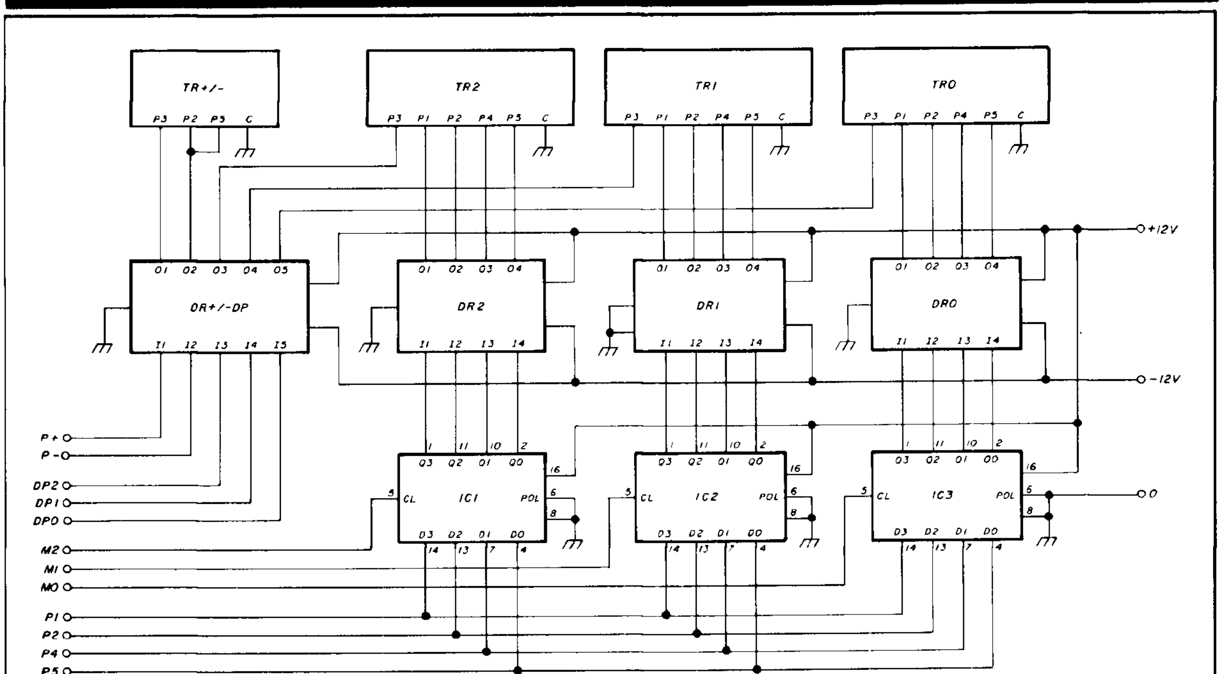
Seven-segment code-to-decimal converter.

FIGURE 9



Three-digit DVM suitable for driving a row of four bistable transducers.

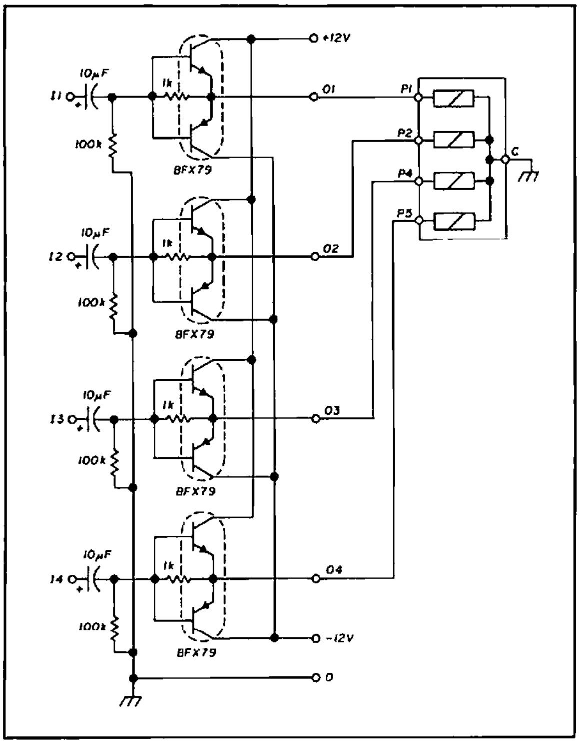
FIGURE 10



Control and drive circuit for the row of four bistable transducers.

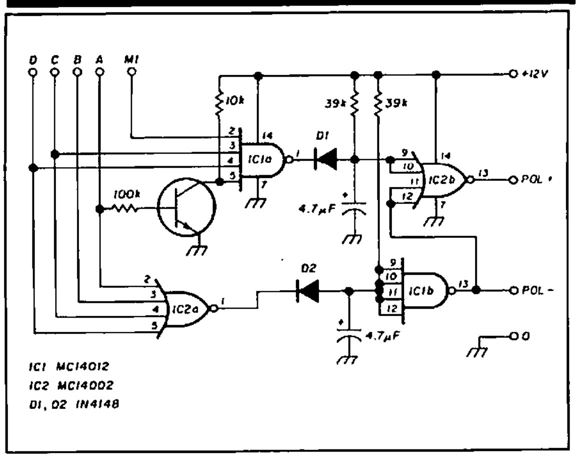
SW1 is the "mode;" SW2 is the "range" selector. SW3 provides polarity inversion, while closing SW4. The last measured data is saved into the reading row. The dual op amp (IC1) is a DC amplifier, the gain of which — in the lowest V/A range — is changed by T1 from 1 to 10. Dual op amp IC2 forms a precision AC-to-DC converter; dual op amp IC3 is the ohm-to-volt converter.

FIGURE 11



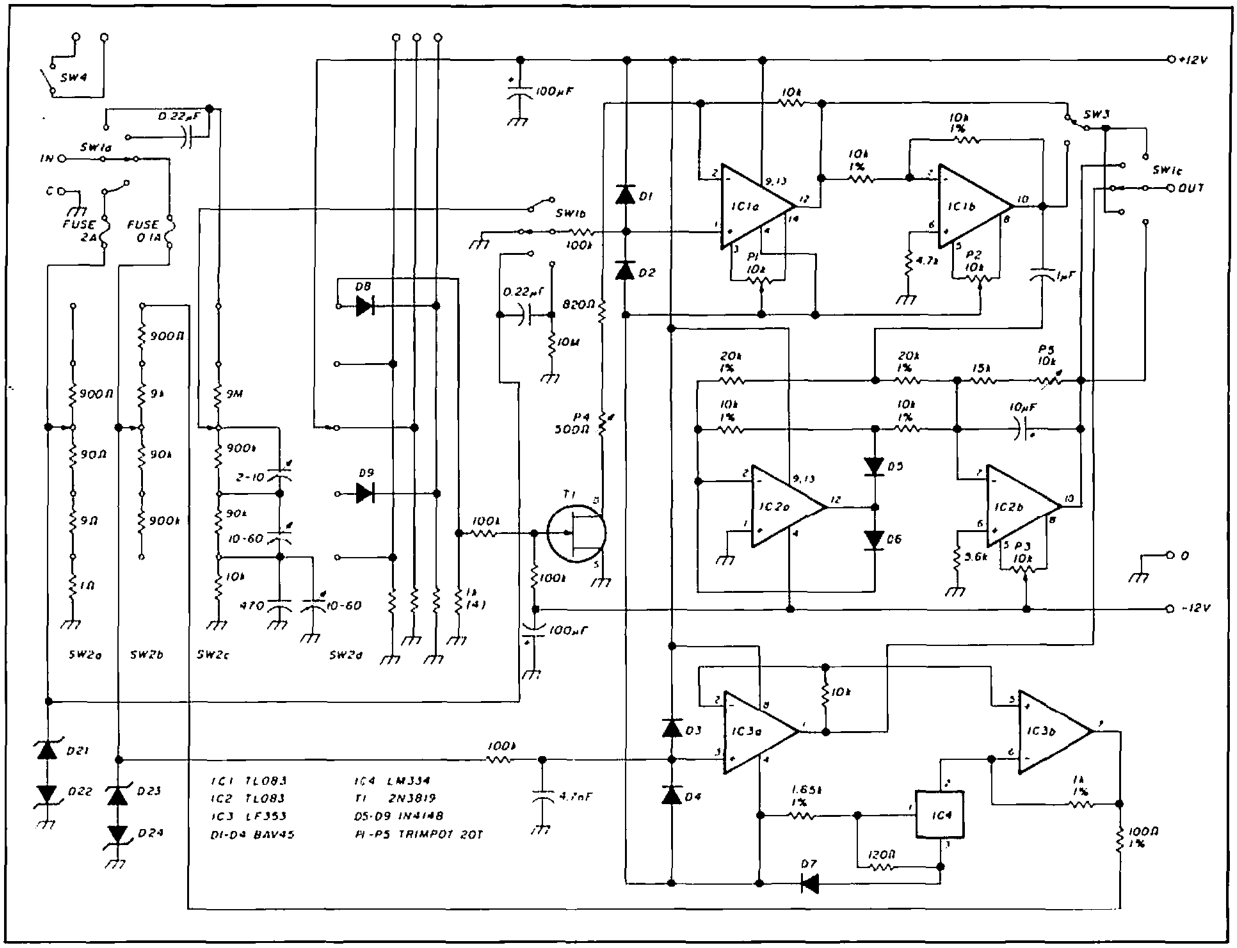
Quad differentiation driver (DR in *fig. 10*).

FIGURE 12



Schematic of the polarity information decoding circuit.

FIGURE 13



DVM front end suitable for driving the DVM of *fig. 9.*

FIGURE 13

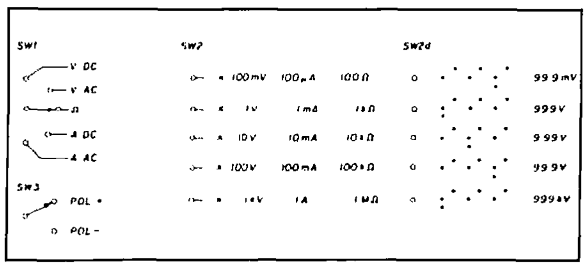
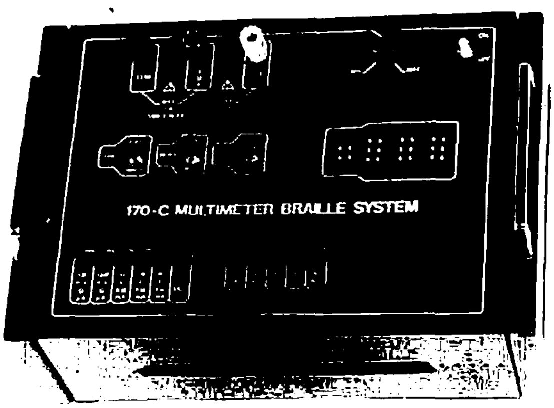


PHOTO C



Braille DMM equipped with a row of four monostable transducers. Ranges: 0.1 V to kV 0.1 mA to 10 A DC/AC; 100 ohm to 10 meg. Reading mode: static/vibrating. Power supply: 220 Vac.
Manufactured by P.A.M., Pertegada (Udine, Italy)

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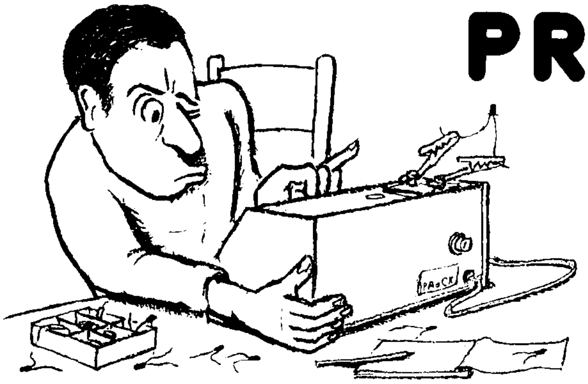
Article I **HAM RADIO**



PRACTICALLY SPEAKING

Joe Carr, K4IPV

RF wattmeters and antenna VSWR meters

The RF power meter (or wattmeter) is a "must" for Amateurs. This instrument measures the output power of the transmitter, and displays the result in watts or some related unit. Antenna VSWR (voltage standing wave ratio) meters are closely related to the RF wattmeter. These instruments also examine the output of the transmitter, and give a relative indication of output power. They can be calibrated to display the dimensionless units of VSWR. Many modern instruments, which I'll discuss this month, combine both RF power and VSWR measurement capabilities.

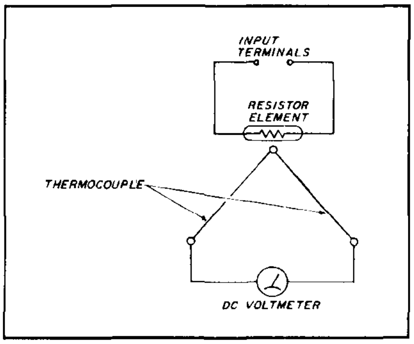
Measuring RF power

Measuring RF power has been notoriously difficult — except, perhaps, in the case of continous wave (CW) sources that produce well-behaved sine waves. Even in that limited case, however, some measurement methods are distinctly better than others.

One of the earliest forms of practical RF power measurement was the thermocouple RF ammeter (see **fig. 1**). This instrument works by dissipating a small amount of power in a small resistance inside the meter, and then measuring the heat generated with a thermocouple. A DC current meter monitors the output of the thermocouple device, and indicates the level of current flowing in the heating element. Because it works on the basis of power dissipated heating a resistance, a thermocouple RF ammeter is inherently an RMS reading device. This feature makes it very useful for taking average power measurements. If you know the RMS current and the resistive component of the load impedance, and if the reactive component is zero or very low, then you can determine RF power from the expression:

$$P = I^2 \times R_l \qquad (1)$$

FIGURE 1

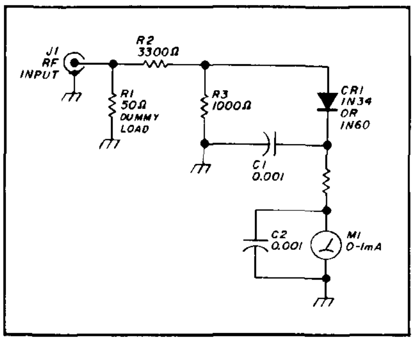


Schematic representation of a thermocouple RF ammeter.

There is a significant problem that keeps thermocouple RF ammeters from being universally used in RF power measurement — they are highly frequency dependent. Even at low frequencies it's recommended that the meters be mounted on insulating material with at least 3/8-inch spacing between the meter and its metal cabinet. Despite that precaution, there's a strong frequency dependence that renders the meter less useful at higher frequencies. Some meters are advertised to operate into the low VHF region, but a note of caution is necessary. The recommendation requires a copy of the calibrated frequency response curve for that particular meter so that a correction factor can be added or subtracted from the reading. At 10 MHz and higher, the readings of the thermocouple RF ammeter must be taken with a certain amount of skepticism, unless the original calibration chart is available.

You can also check RF power by measuring the voltage across the load resistance (see **fig. 2**). In the circuit of **fig. 2**, the RF voltage appearing across the load is scaled downward to a level compatible with the voltmeter by resistor voltage divider R2/R3. The output

FIGURE 2



Schematic of a simple diode voltmeter used for measuring RF power of an unmodulated sinusoidal waveform.

of this divider is rectified by CR1, and filtered to DC by the action of capacitor C2.

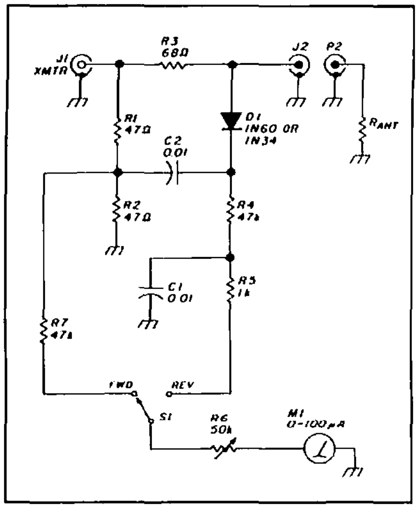
The method of measuring the voltage in a simple diode voltmeter is valid only if the RF signal is unmodulated and has a sinusoidal waveshape. While these criteria are met in many transmitters, they aren't universal. If the voltmeter circuit is peak reading, as in **fig. 2**, then the peak power is:

$$P = (Vo^2)/R1 \qquad (2)$$

The average power is then found by multiplying the peak power by 0.707. Some meter circuits include voltage dividers that precede the meter and thereby convert the reading to RMS, thus also converting the power to average power. Again, it must be stressed that terms like "RMS," "average," and "peak" have meaning only when the input RF signal is both unmodulated and sinusoidal. Otherwise, the readings are meaningless unless calibrated against some other source.

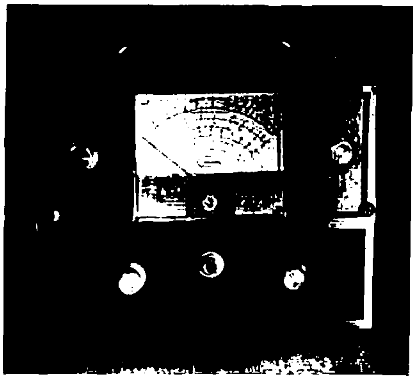
It's also possible to use various bridge methods to measure RF power. **Figure 3** shows a bridge set up to measure both forward and reverse power. (**Photo A** is a commercial version used for CB servicing.) This circuit was once popular for VSWR meters. There are four elements in this quasi-Wheatstone bridge circuit: R1,

FIGURE 3



VSWR bridge circuit for measuring both forward and reverse power.

PHOTO A



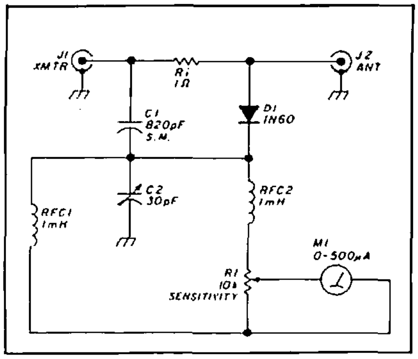
Commercial forward/reflected reading power meter.

R2, R3, and the antenna impedance (connected to the bridge at J2). If R_{ant} is the antenna resistance, we know that the bridge is in balance (the null condition) when the ratios R1/R2 and R3/R_{ant} are equal. In an ideal situation, resistor R3 will have a resistance equal to R_{ant}, but that may severely limit the usefulness of the bridge. In some cases, the bridge will use a compromise value like 68 ohms for R3. A resistor of this type will be usable on both 50 and 75-ohm antenna systems with little error. Typically, these meters are designed to read the relative power level rather than the actual power.

This type of meter allows you to make an accurate measurement of VSWR by proper calibration. With the switch in the FORWARD position, and RF power applied to J1 ("XMTR"), potentiometer R6 is adjusted to produce a full-scale deflection on meter M1. When the switch is then set to the REVERSE position, the meter will read reverse power relative to the VSWR. An appropriate VSWR scale is provided.

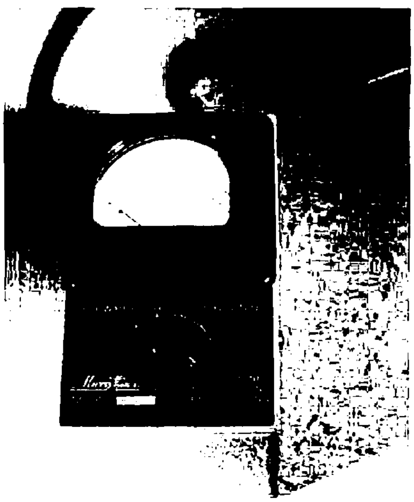
There is a significant problem with the bridge in **fig. 3**. It can't be left in the circuit during transmission because it dissipates a considerable amount of RF power in the internal resistances. These meters, during the time when they were popular, had switches that bypassed the bridge when transmitting. The bridge was only in the circuit when making a measurement.

FIGURE 4



An improved Micromatch circuit using a capacitor/resistor bridge circuit for power measurements.

PHOTO B



Micromatch forward/reflected reading power meter with three power scales.

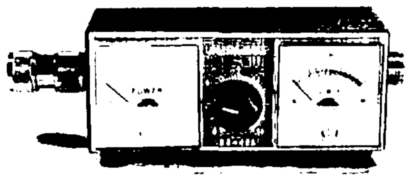
An improved bridge circuit, the capacitor/resistor bridge, is shown in **fig. 4**. This circuit is called the "Micromatch" bridge. You can see immediately that the Micromatch is an improvement over the conventional bridge because it uses only 1 ohm in series with the line (R_i). This resistor dissipates considerably less power than the resistance used in the previous example. Because of this low value resistance, you can leave the Micromatch in the line while transmitting. Recall that the ratios of the bridge arms must be equal for the null condition to occur. In this case, the capacitive reactance ratio of C1/C2 must match the resistance ratio $R1/R_{ant}$. For a 50-ohm antenna, the ratio is 1:50; for 75-ohm antennas it's 1:75 (or, for the compromise situation, 1:68). The small-value trimmer capacitor (C2) must be adjusted for a reactance ratio with C1 of 1:50, 1:75, or 1:68, depending upon how the bridge is set up.

The sensitivity control can be used to calibrate the meter. In one version of the Micromatch (shown in **photo B**) there are three power ranges — 10, 100, and 1000 watts. Each range has its own sensitivity control, and these are switched in and out of the circuit as needed.

The Monomatch bridge circuit in **fig. 5** is the instrument of choice for most HF and low VHF applications. In the Monomatch design, the transmission line is segment B; RF sampling elements are formed by segments A and C. Although the original designs were based on a coaxial cable sensor, later versions used either printed circuit foil transmission line segments or parallel brass rods for A, B, and C.

The sensor unit is basically a directional coupler with a detector element for both forward and reverse directions. For best accuracy diodes CR1 and CR2 should be matched, as should R1 and R2. The resistance of R1 and R2 should match the transmission line surge impedance, although in many instruments a 68-ohm compromise resistance is used.

PHOTO C



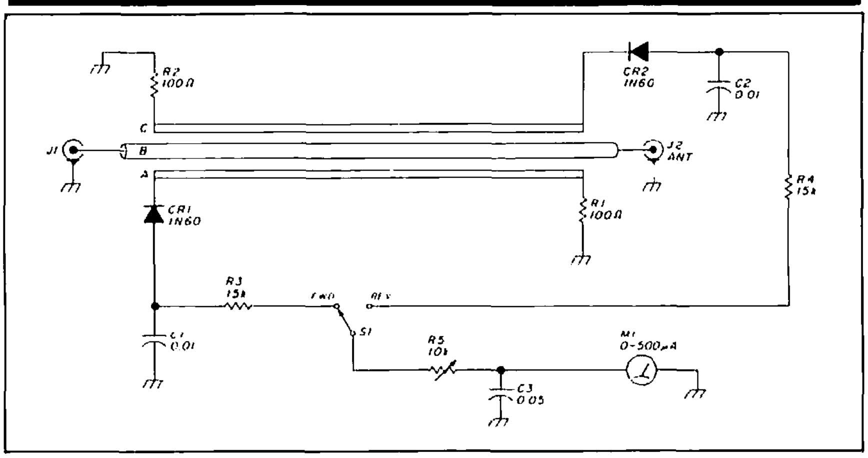
Midland forward/reflected reading power meter and VSWR meter combined in one housing.

The circuit shown in **fig. 5** uses a single DC meter movement to monitor the output power. Many modern designs use two meters (one each for forward and reverse power), as in **photo C**.

One of the latest designs in VSWR meter sensors is the current transformer assembly shown in **fig. 6**. In this instrument a single-turn ferrite-toroid transformer is used as the directional sensor. The transmission line passing through the hole in the toroid "doughnut" forms the primary winding of a broadband RF transformer. The secondary, which consists of 10 to 40 turns of small enamel wire, is connected to a measurement bridge circuit (C1 + C2 + load) with a rectified DC output.

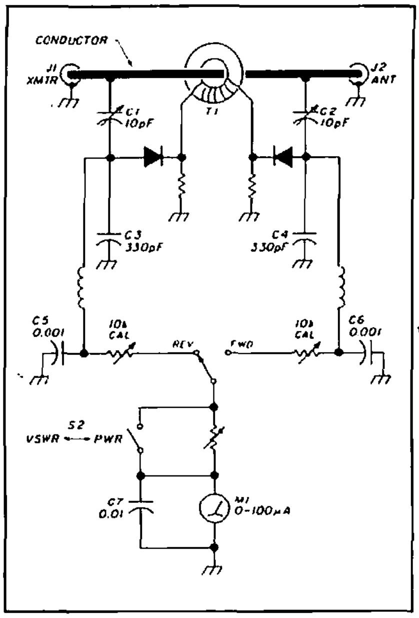
Photo D shows the Heath Model HM-102 high-frequency VSWR/Power meter. The sensor in the HM-102 is a variant of the current transformer

FIGURE 5



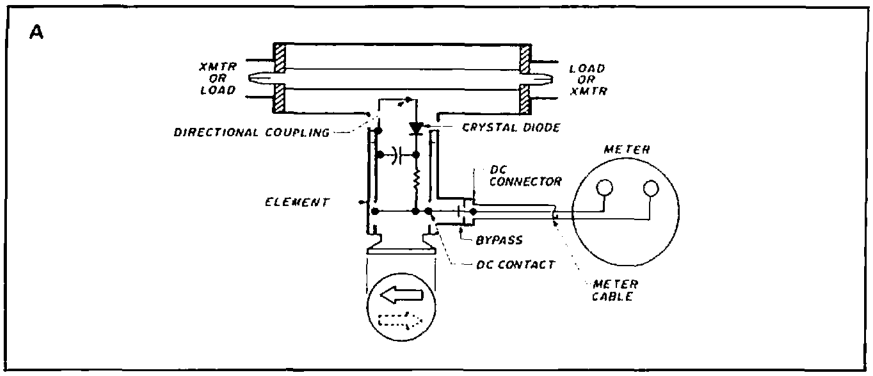
Schematic of the Monomatch bridge circuit using RF sampling.

FIGURE 6



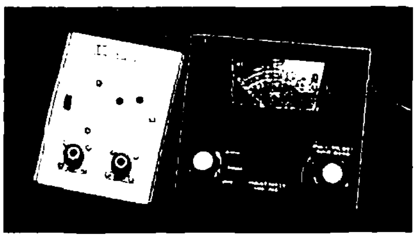
Schematic of the latest design for VSWR bridges using a current transformer made from a single-turn ferrite toroid acting as a directional sensor.

FIGURE 7



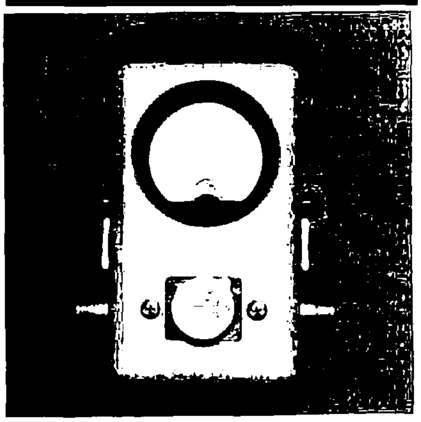
Detail of the directional coupler transmission line assembly used for Thruline measurements.

PHOTO D



Heath combined power/VSWR meter with wired remote sensor.

PHOTO E



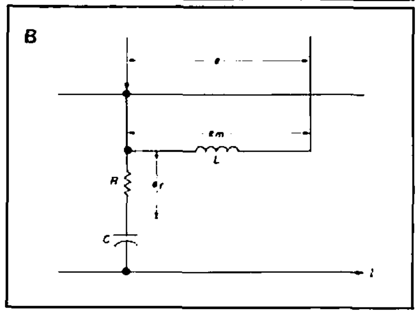
Bird Thruline forward/reflected reading power meter.

method and L1 is the toroid transformer. This instrument measures both forward and reflected power, and can be calibrated to measure VSWR.

The Bird Model 43 Thruline® RF wattmeter shown in **photo E** has been one of the industry standards in communications service work for years. Although it's slightly more expensive than lesser instruments, it's also versatile, accurate, and rugged. The Thruline meter can be inserted into the transmission line of an antenna system with so little loss that it can be left permanently in the line during normal operations. The Model 43 Thruline is popular with land-based mobile and marine radio technicians.

The heart of the Thruline meter is the directional coupler transmission line assembly shown in **fig. 7A**. It is connected in series with the antenna or dummy load transmission line. The plug-in directional element can be rotated 180 degrees to measure both forward and reverse power levels. A sampling loop and diode detector are contained within each plug-in element. The main RF barrel is actually a special coaxial line segment with a 50-ohm characteristic impedance. The Thruline sensor works because of mutual inductance between the sample loop and center conductor of the coaxial element. **Figure 7B** shows an equivalent circuit. The output voltage from the sampler (*e*) is *the sum* of two voltages, e_r and e_m. Voltage e_r is created by the voltage divider action of R and

FIGURE 7



Equivalent circuit demonstrating the theory of operation for the Thruline sensor.

C on transmission line voltage E. If R is much less than X_c, then the expression for e_r may be written

$$e_r = RE/X_c = RE(jwC) \quad (3)$$

Voltage e_m, on the other hand, is due to mutual inductance and is expressed by

$$e_m = I(jw) \pm M \quad (4)$$

You now have the expression for both factors that contribute to the total voltage e. You know that

$$e = e_r + e_m \quad (5)$$

so, by substitution,

$$e = jwM((E/Z_o) \pm I) \quad (6)$$

By recognizing that, at any given point in a transmission line, E is the sum of the forward (E_f) and reflected (E_r) voltages, and that the line current is equal to

$$I = \frac{E_f}{Z_o} - \frac{E_r}{Z_o} \quad (7)$$

where Z_o is the transmission line

impedance, you may specify e in the forms

$$e = \frac{jwM(2Ef)}{Z_0} \qquad (8)$$

and

$$e = \frac{j\,w\,M(2Er)}{Z_0} \qquad (9)$$

The output voltage e of the coupler, then, is proportional to the mutual inductance and frequency (by virtue of jwM). But the manufacturer terminates R in a capacitive reactance, so the frequency dependence is lessened. Therefore, each element is custom calibrated for a specific frequency and power range. Beyond the specified range for any given element, however, performance isn't guaranteed. There are a large number of elements available that cover most Amateur Radio applications.

Conclusion

The RF wattmeter, and/or its cousin the VSWR meter, are essential items in the Amateur Radio operator's bag of tricks. Both these instruments are used for adjusting antennas and testing the output of radio transmitters.

Article J **HAM RADIO**

A SIMPLE PROM PROGRAMMER

An easy alternative for entering short programs

By Michael Moore, WV6A, 2221 West Manly Avenue, Santa Ana, California 92704

Programmable Read Only Memories (PROMs) are devices used in circuits requiring a pattern of "ones and zeros" in a specific sequence. One use is to store computer programs; another is to store a sequence of digital numbers accessible by a counter attached to the memory address lines. In this way, you can make a counter circuit that generates a sequence like 1, 2, 3, 4, etc. output the sequence 5, 9, 4, etc. This is useful for doing operations like code conversion. (I have seen an example of International Morse Code being converted to upper case ASCII.)

In the September 1988 issue of *Ham Radio*[1], I demonstrated how to use a PROM in a DTMF signaling circuit. I built the circuit to monitor the output of a 2-meter handie-talkie radio for DTMF tones so that I could receive signals from other operators without having to stay glued to the radio. The circuit converts the tones it hears into a digital code and compares this code with one I've stored in a PROM. After the circuit finds a match, it increments a counter that addresses the PROM, readying it for the next DTMF tone comparison. When there are four valid compares, an alarm lets me know that somebody who has my four-digit code is trying to reach me.

About the PROM

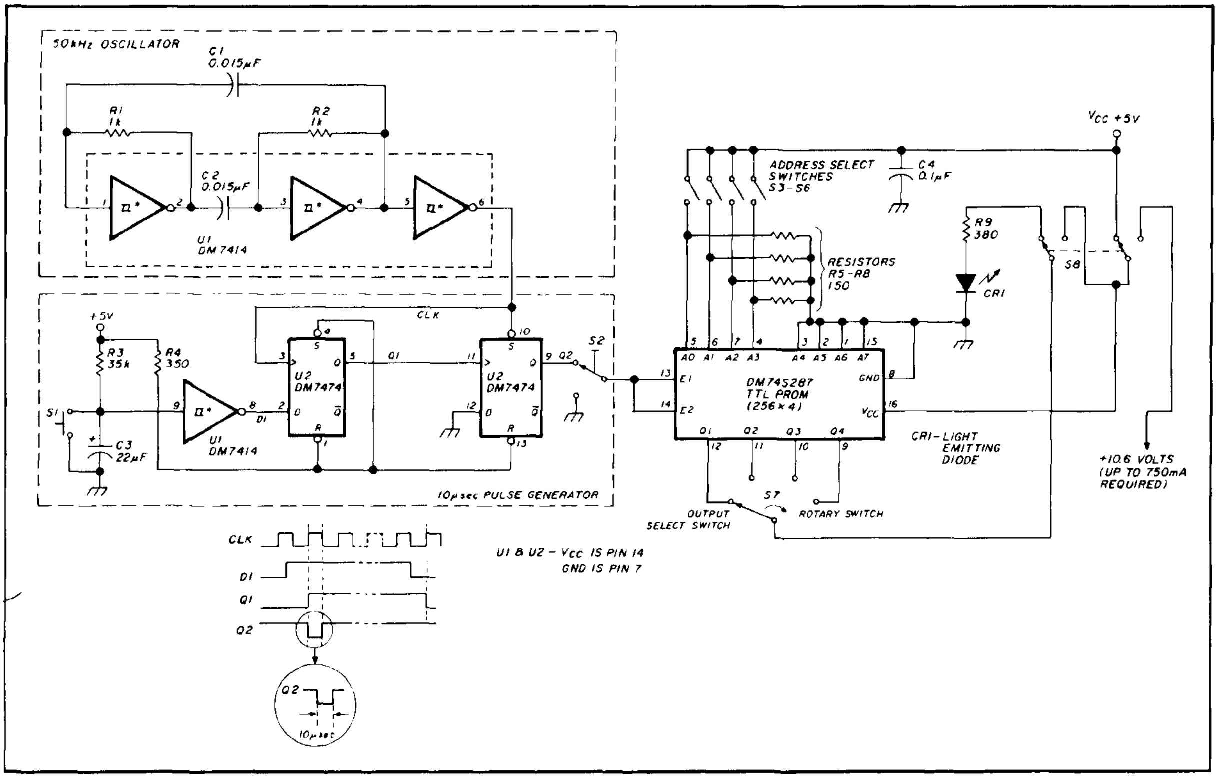
The circuit used a DM74S287 manufactured by National Semiconductor Corporation. It's one of a family of devices featuring titanium-tungsten (Ti:W) fuse links designed to "blow" when 10.5 volts is applied across them. The PROMs are shipped from the factory with all fuses intact; this produces lows (zeros) in all locations. You can program a high level into any location by following the programming instructions to blow that fuse. This is an irreversible procedure — once a fuse is blown it will always produce a high at that location. (A fuse left intact can always be blown later.)

The DM74S287 memory is organized as 256 words, each 4 bits long. Two enable lines control the device's output. When the PROM is enabled, the outputs represent the contents of the word selected by its address line states. There are eight address lines allowing for 256 combinations, or one combination for each 4-bit word. When the enable lines are high (disabled) the *outputs revert to "off," or high-impedance state.*

Don't confuse these PROMS with erasable programmable read only memories (EPROMs) or electrically erasable PROMs (EEPROMs). EPROMs have special circuits allowing the memory contents, once programmed, to be erased when ultraviolet light is applied through a quartz window in the top of the package. Once erased, it can be reprogrammed. The EEPROM is erased when certain high voltage levels are applied to specific pins.

There are several manufacturers of fusible-link PROMs; Texas Instruments and Advanced Micro Devices are two. These manufacturers use different

FIGURE 1



The schematic for the PROM programmer.

materials for their fuses, making the requirements to burn out the fuses different. To circumvent this problem, commercial PROM programming machines use "personality modules." They reconfigure the programmer so that the programming is done using the original PROM manufacturer's instructions. Failure to specify the manufacturer to these PROM programming machines can result in a failed programming operation or a failed PROM.

The PROM programmer is simple to construct and can manually blow the few locations required for National Semiconductor Corporation's DM74S287 PROM. I built the whole thing on a breadboard and tore it down later to do another project. I've since built several other signaling devices and had to rebuild the programmer. It's now housed in a small plastic box complete with a light-emitting diode (LED), address selection switches, mode switch, programming switches, and a socket for the PROM. External leads supply the voltages required.

Programming the PROM

The manufacturer's instructions indicate that programming should be done between 15 and 30 degrees Celsius. Address and enable inputs can only be driven with TTL logic levels during programming and verification. To program the device, select the word to be programmed using the address select switches. These switches, depending on their setting, put either a high or a low on the four *least significant* address bits. (I only had to program six locations for the DTMF decoder, so it was possible to hard wire the four most significant address lines to zero). Next, disable the programmer by applying a high level to one or both of the "active low" chip enable inputs.

Now apply 10.5 volts to both Vcc and the output to be programmed. Do this simultaneously, or to Vcc first and then the output. (You'll incur damage if the output sees the 10.5 volts before Vcc). It's *critical* that only one output at a time is programmed, because the internal circuits can supply programming current up to only 750 mA at a time. You must leave outputs not being programmed open or connected to a high impedance source of 20 k minimum. To continue, enable the device briefly with a low level pulse of 10 (minimum 9 and maximum of 11) μS; this should blow the selected fuse. Now verify the programming by returning Vcc to 5 volts, connecting the output to a LED, and re-enabling the device. If the bit was not programmed, repeat the operation — up to 10 times, according to the manufacturer. (I've yet to do this more than four times.) The manufacturer recommends

that, once you've done your verification, five additional programming pulses should be applied to the bit being programmed. This completes the programming for that bit. Move on to the next one and repeat the process until programming is completed.

The circuit shown in **fig. 1** uses two Schmitt trigger inverters of a single DM7414 (this package contains six inverters) with feedback to produce a simple 50-kHz oscillator. A third inverter squares up the resulting output. Simple inverters like those in the DM7404 will also work. But the frequency of oscillation is less dependent on the supply voltage when you use the DM7414 because of the built-in hysteresis. If you have access to an oscilloscope or frequency counter you can adjust the values of C1, C2, R1, and R2 to obtain a good square wave with a 20-μS period measured on pin 6 of U1. I've experimented with several DM7414 and DM5414 (the military versions of the DM7414s), as well as several examples of resistors at 1 k and several 0.015-μF capacitors, and the frequency I observed was pretty close to the 50 kHz. The time during which the output is at a high level (10 μS) is the length of the programming pulse generated by U2.

If you can't get hold of an oscilloscope or other timing device, a good alternative would be a substitute oscillator using a 100-kHz crystal. Divide it by 2 to produce a clock of 50 kHz with a 50-percent duty cycle, so that the low-level excursion is 10 μS. You can do this with a DM7474 D-type flip-flop with the inverting output wired back to the D input and the oscillator output applied to the D flip-flop's clock input.

The pulse generator uses another of the Schmitt trigger inverters with C3 and R3 to debounce the pulse from the momentary push button switch S1. This activates the two D-type flip-flops of U2, which is clocked from the oscillator to produce the 10-μS PROM enabling pulse. Switch S2 is a momentary push button switch, used to select between the 10-μS pulse for programming or continuous enabling during the verification phase. The released position of this switch should select the pulse generator output, with continuous PROM enabling only when the switch is held down. In the held-down position it enables the PROM so that the outputs can be displayed on the LED.

Switches S3 through S6 are the address selection switches. You can add more if necessary to program more words of the PROM. S7 is a rotary-type switch that selects the output bit to be programmed. Switch S8 is a double-pole switch — one pole selects the power supply voltage to the Vcc pin (16) of the PROM; the other either directs 10.5 volts to the output, or outputs the PROM itself to the LED.

The resistor at R4 pulls up the unused inputs of U2; R9 is a current-limiting resistor for the LED. Capacitor C4 is a Vcc decoupling capacitor and should be located as close to the oscillator U1 as possible.

Example of a programming operation

Suppose you want to insert the code 0100 (decimal 4) at memory location 5. Close the switches controlling address selection for the A3 and A0 inputs of the PROM (for a high level), and set A2 and A1 open. Next, set S8 to direct the PROM output to the LED and the Vcc to be at 5 volts. Call this the "verify" position. Depress switch S2 to enable the PROM (the "display" position). Rotating S7 through each of the four output positions should show that all outputs are low; that is, the LED will remain off. Now select output Q3 with S7, and S2 is released — ready for the PROM to be enabled from the pulse generator. Only after S2 has been released can you move S8 to the programming position, by selecting the 10.5 volts to the output pin and Vcc pin, respectively.

Depress and release the momentary pushbutton switch, S1; this enables the PROM for 10 μS. Then return switch S8 to the verify position and push S2 to display the output. If the bit was programmed correctly the LED will light. If it does, release S2 and then return S8 to the programming position — in that order. Depress push button switch S1 five more times in succession. If the bit fails to program on the first attempt, you can repeat the sequence of switch settings. Remember, however, to ensure that S2 is never in the display position (depressed when S8 is in the programming position).

To generate the power supplies I used four NiCd batteries in series. Together they produce about 4.8 volts for the nominal 5-volt supply and a variable power supply set to 10.5 volts for the programming supply. I used a multimeter to adjust this to within 0.5 volt. If a variable power supply is not available, connecting seven 1.5-volt alkaline cells in series will work. Remember that this supply should be capable of delivering **750 mA** during the 10-μS programming pulse.

For fused PROMs made by other manufacturers the same principles hold; however, each specifies differing voltage levels during longer or shorter programming pulses. Changing the values of C1, C2, R1, and R2 will vary the oscillator frequency up to about 10 MHz. This gives you some idea as to the range of pulses that can be produced. When blowing a PROM it's best to make a careful list of each bit that you need to change to a high level and methodically work your way through them. I don't recommend trying to blow a PROM for a large computer program in this fashion — but for simple uses like code converters, or for the DTMF tone signaling circuit, it works very well and doesn't take long to put together.

References

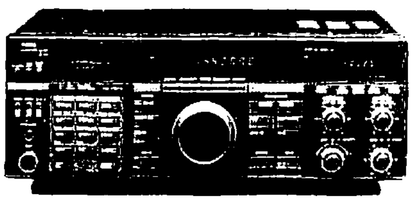
1. Michael S.R. Moore, WV6A, "A DTMF Tone Signaling Circuit," *Ham Radio*, September 1988, page 42.

Article K **HAM RADIO**

NEW products

New gear for the satellite communicator.

The Kenwood TS-790A covers 144, 450, and 1200 MHz with enhancements like Doppler shift compensation for the VHF, UHF, and satellite "power user." Automatic Lock Tuning (ALT) on 1200 MHz eliminates frequency drift. Power output is 45 watts on 144 MHz, 40 watts on 450 MHz, and 10 watts on 1200 MHz. (The 1200-MHz section is an optional module.) The TS-790A is pending FCC approval.



TS-790A features include:

- High stability VFO.
- 59 multi-function memory channels.
- Operation on 13.8 Vdc.
- Multiple scanning and scan stop functions.
- 500-Hz CW filter built in.
- Interference reduction controls.
- Packet radio terminal.
- CTCSS encoder built in.
- Mode switch confirmation of USB, LSB, CW, or FM selection with Morse Code.
- Dual Watch for reception of two bands at the same time.
- Automatic mode and automatic repeat offset selection.
- Direct keyboard frequency entry.
- Voice synthesizer and computer control option.

The retail price of the TS-790A is $1999.95. For more information contact Kenwood, 2201 E. Dominquez Street, Long Beach, California 90810.

UAI-10 Universal Audio Interface

The Creative Control Products UAI-10 Universal Audio Interface board is a low cost, easy to interface repeater and link audio mixer featuring DTMF mute, and link monitor-mix control.

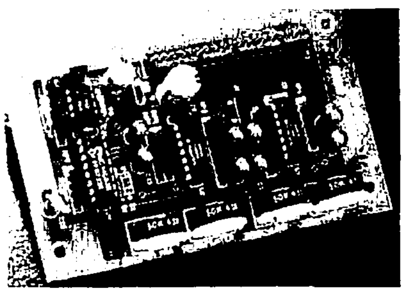
Audio inputs are: repeater, link, control receiver, CW-Tone, and an auxiliary input for other audio sources like a local microphone. Audio outputs are: repeater, link, and a DTMF output for the DTMF decoder on your controller. Each audio output is adjustable to the level required by your system.

Control inputs to the UAI-10 consist of repeater COS (which is selectable high or low), DTMF mute, and an auxiliary output from your controller for the link mute function.

The UAI-10 has provisions to mute the DTMF tones from the repeater transmit audio. The ability to mute or pass DTMF tones out the link transmit audio is provided via a jumper on the circuit board.

Normally full audio is present at the repeater transmitter audio output. Whenever the repeater COS is activated, both the repeater and link audio are mixed together resulting in the condition called Monitor-Mix. This monitor-mix audio is adjustable so that the link receiver audio can be lower in volume than the repeater receiver audio. Also, whenever the auxiliary control input is activated, the link receive audio will be completely muted upon repeater COS activity. Either mute or monitor-mix operation is selectable so that normal repeater receiver audio will not be overpowered by the link receiver's audio.

Each UAI-10 comes assembled and tested and carries a one-year warranty. The UAI-10, with manual is available for immediate shipment at an introductory price of $44.00.



For more information on the UAI-10, contact Creative Control Products, 3185 Bunting Avenue, Grand Junction, Colorado, 81504 (303) 434-9405.

Circle #301 on Reader Service Card.

New dealers announced

Kantronics, Inc. announces the appointment of Associated Radio of Overland Park, Kansas and Rivendale Electronics of Derry, New Hampshire as new Amateur dealers for the Kantronics line of Amateur Radio products.

For more information, please contact: Kantronics, Inc. 1202 E. 23rd Street, Lawrence, Kansas 66046.

PC HF FAX facsimile reception system for IBM PC™ computers

Software Systems Consulting has announced a new way to receive facsimile information from HF SSB receivers using an IBM™ or compatible personal computer. The HF FAX system produces images with gray scale or color. The system contains everything you need to connect your computer and your HF receiver. It consists of an A/D demodulator cable, software, instruction manual, and tutorial tape cassette.

Minimum system requirements are: an HF SSB receiver; an IBM PC or true compatible; MS DOS 2.1 or higher; 384K RAM; a Hercules, CGA, or EGA video adapter card; and a serial port. A parallel printer and an audio cassette player are optional.

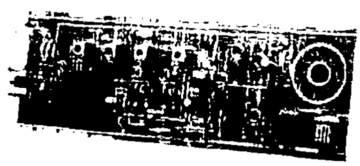
The PC HF FAX software is menu driven and has a tuning scope feature for FAX capture. The scan rate is variable to allow for the different types of FAX transmissions found on HF (ie., Weather FAX, news wire services, etc.). Once the parameters are set to match transmission rates to the computer's internal clock, the "auto mode" can be used to detect the beginning of a new transmission, capture it, and save to disk for future use.

PC HF FAX sells for $79.95, and is available from Software Systems Consulting, Amateur Radio Group, 1303 S. Ola Vista, San Clemente, California 92672.

Circle #302 on Reader Service Card.

"Super heterodyne" receiver

The Elenco Superhet 550 AM Radio Kit is a "super heterodyne" receiver of standard AM (amplitude modulated) broadcast frequencies. It uses seven transistors. The Superhet 550 lets you place parts over their corresponding symbols in the schematic drawing on the surface of the printed circuit board during assembly. This maximizes the learning process and keeps the chances of assembly error at a minimum.



An assembly, lesson, and theory of operation manual is included. Priced at $19.95, the Superhet 550 makes an excellent project for classroom studies.

For additional information contact Elenco Electronics, Inc., 150 West Carpenter Avenue, Wheeling, Illinois 60090.

Circle #303 on Reader Service Card.

NEW products

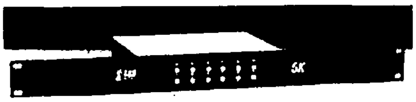
New display cabinet option

S-COM Industries has a new display cabinet option for its 5K Repeater Controller. The cabinet may be retrofitted to any 5K controller without soldering or rewiring.

The display cabinet has a non-chipping black anodized front panel, white graphics, and hidden fasteners to eliminate unsightly screw heads and other hardware.

Large, red Hewlett-Packard AlGaAs LED lamps give circuit status data (i.e., Receiver COR, Transmitter PTT, CTCSS Decoder, Control Receiver COR, DTMF Data Valid, Power On, Logic Inputs 1, 2, 3, and Logic Outputs 1, 2, and 3). The LEDs feature high light output while consuming 1 mA each.

A conductive iridite-plated chassis box reduces RFI and houses the 5K board, display Board, and an optional Audio Delay Module.



The cabinet has cutouts for the 5K's power and input/output connectors, and uses PEM fasteners to eliminate nuts and standoffs. A ribbon cable assembly attaches to connectors located on the 5K and display boards for easy installation.

The assembled and tested display cabinet is priced at $69 plus $5 shipping and handling. A similar cabinet is available without the display feature. Contact S-Com Industries, P.O. Box 8921, Fort Collins, Colorado 80524. Telephone 303-493-8316.

Circle #304 on Reader Service Card.

NP1055

New book explains different communication modes

Advanced Electronic Applications has just released its new publication for Radio Amateurs interested in digital communication, *Digital Communications With Amateur Radio*. It gives a basic understanding of many different communication modes, with major emphasis on packet radio. The 160-page paperback uses dozens of illustrations to make difficult subjects easy to understand.

In addition to theoretical explanations, *Digital Communications With Amateur Radio* gives hands-on examples of computer-to-radio interfacing. This book is perfect for both the Radio Amateur and computer hobbyist.

AEA created this special book in cooperation with Master Publishing of Richardson, Texas. The original book was written for, and is available from, Radio Shack. The AEA book is available through AEA authorized dealers and *Ham Radio* Bookstore. This book is an excellent source of packet information most requested by Radio Amateurs. The suggested retail price is $9.95 (plus $3.50 shipping and handling from *Ham Radio* Bookstore).

For more information contact Advanced Electronic Applications, Inc., P.O. Box C2160, Bldg. O & P, 2006 196th SW, Lynnwood, Washington 98036-0918.

Circle #305 on Reader Service Card.

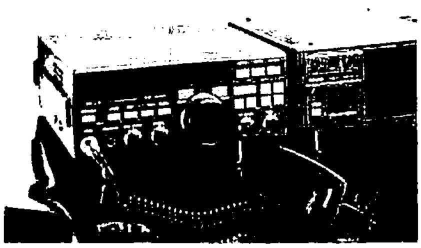
New all-mode transceiver from Heath

Heath Company has introduced the SB-1400 All-Mode Transceiver. This new transceiver provides all-band, all-mode coverage and 100 watts of transmit power.

The SB-1400 is sold assembled at a suggested net price of $799.95. (Product specifications and prices are subject to change without notice.)

Available accessories include: a 20-amp power supply with built-in speaker, an FM module, handheld microphone, mobile bracket, and a switching relay that may be required for some linear amplifiers.

The SB-1400 comes with after-sale support through the 70 Heath/Zenith stores in the U.S. and Canada, or direct from the factory. The transceiver also comes with an industry-recognized user's manual. To order the SB-1400, call toll-free 1-800-253-0570.



For a complete listing of products, write for the Heathkit catalog at: Heath Company, Department 350-036, Benton Harbor, Michigan 49022 or call toll-free 1-800-44-HEATH.

New dealer and distributor announced

Kantronics, Inc. has appointed RJM of Boise, Idaho as a new dealer for the Kantronics line of Amateur Radio products and Morocom, Inc. of Alexandria, Virginia as a Kantronics distributor for countries like Peru, Boliva, Ecuador, Columbia, and Mexico.

For more information, please contact: Kantronics, Inc. 1202 E 23rd Street, Lawrence, Kansas 66046.

New full-function software package

The Amateur Radio Operating System (ARS), written by Ron Stange, WA4PYF, is a modular software system for IBM PC and compatibles. It is a full-function software package for both Novices and seasoned Amateur Radio operators.

ARS software is offered in functional modules. After purchasing the BASE module, you need only buy those modules that support your own field of interest.

The ARS base module can be ordered for $39.95 to Fundamental Services, Dept R, 1546 Peaceful Lane N., Clearwater, Florida 34616. Florida residents add $2.40 sales tax. Demonstration diskettes are available for $10, discounted on the next purchase.

Dealer and distributor inquiries are invited.

Yaesu USA creates design team of Amateur Radio operators

Yaesu USA invites Amateur Radio operators to apply for the company's special design advisory council. They will meet with Yaesu's management staff Wednesday, June 14 throughFriday, June 16, 1989.

The operators will be asked what features they'd like to see in Amateur Radio equipment. Eleven applicants will be chosen – one from each call district and one at Dayton HamVention '89. Yaesu will fly those selected to Southern California. The team will stay at the Disneyland Hotel, tour the Jet Propulsion Laboratory, and receive passes to Disneyland.

The first ten members will be chosen from applications postmarked by April 7, 1989. The last team member will be selected from applications turned in by April 29 at the Yaesu booth at HamVention '89 in Dayton, Ohio.

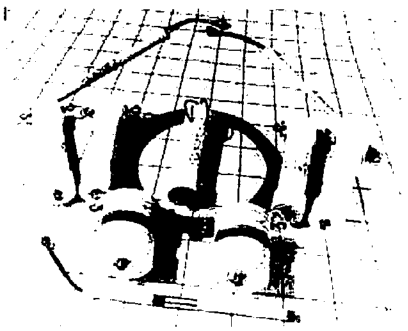
For more information or to obtain an application form, call (800) 999-2070, or write to Yaesu Council, Yaesu USA, 17210 Edwards Road, Cerritos, California 90701.

NEW products

New, comprehensive, balun line

The RADIO WORKS has announced its comprehensive new balun line.

Three models have 4:1 ratios. The B4-1.5K is a general purpose, 80 to 10 meter, ferrite balun. The B4-2K is a wide-band, L-C compensated, ferrite-toroid balun. The B4-2KX is a twin toroid core, L-C compensated design with good output balance and wide operating bandwidth. The power rating is well beyond the legal limit. All models have exceptional electrical specifications, output balance and very high transmission line isolation.



There are 5 models in the 1:1 balun line. The three "C-series" baluns are designed for retrofit applications in wire antennas and beams from 160 through 10 meters. The C1-2K is a 50-ohm low-loss balun; the C75-2K and the C75-4K are 75-ohm models. All have unusually high transmission line isolation and excellent output balance.

The B1-2K and B1-4K are suitable for use with wire antennas of all types. They are "current-type," wide-band, low-loss designs.

The RemoteBalun™ and a Line Isolator™ are two special models. The 4K-LI Line Isolator is useful for preventing RF current from entering the hamshack and causing RF feedback problems. The 4K-LI is available in 50 and 75 ohm models.

The RADIO WORKS RemoteBalun solves the problem of getting open-wire or ladder-line into the ham shack. The RemoteBalun is mounted outside where it connects to the antenna's ladder-line or open-wire transmission line. A short length of special, low-loss, coaxial cable connects the RemoteBalun to your transmatch.

All RADIO WORKS baluns feature rugged cases. Soldered internal connections, and leads are brought outside the case for direct connection to the antenna wire. Each balun is completely potted. Prices begin at $15.95.

For more information write: The Radio Works at Box 6159, Portsmouth, Virginia 23703. An catalog featuring a wide selection of wire antennas, parts, accessories is available.

Circle #306 on Reader Service Card.

NP1080

Self-learning package makes it easy to upgrade

Radio Shack's new General Class-FCC License Preparation package contains everything you need to upgrade from Technician to General Class.

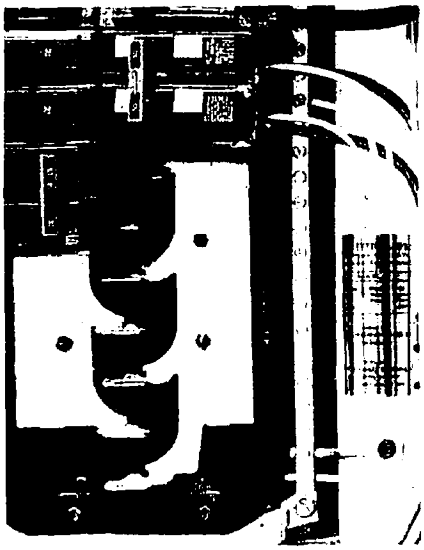
Included are:

- Examination test questions and answers
- Two code tapes for speed building from 5-13 wpm
- Explanation of correct test answers
- Helpful study hints
- FCC form 610 application
- ARRL application

Published by Master Publishing, the New General Class package is available in Radio Shack stores for $19.95.

Surge and lightning arresters

Tytewadd Power Filters manufactures eight models of UL listed secondary surge and lightning arresters for installation directly inside main or sub-distribution electrical panels. One unit, or unit series, connected into one side of any two or three-pole breaker protects the panel and the entire electrical environment of your premises from surges, spikes, and transients from a moderate 130 volts to lightning-induced surges developing 15,000 amps.



Tytewadd devices clamp in 1.5 nanoseconds, at less than 10 percent above the rated (or provided) voltage performance parameters. This lets them dissipate more moderate surges and spikes continuously.

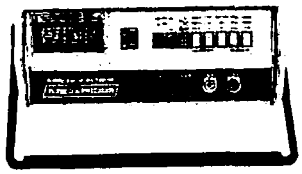
Tytewadd products are warranted for one year, with half-cost replacement thereafter.

For more information contact Tytewadd Power Filters, 704 W. Battlefield Road, Springfield, Missouri 65807.

Circle #307 on Reader Service Card.

Versatile portable multimeter

The Elenco Digital Bench Multimeter Model M-4500 is a versatile 4-1/2 digit portable instrument for use in general electronics maintenance, production, and the laboratory. It has a built-in



battery pack providing 6,000 hours of continuous operation. It features 0.05 percent DCV accuracy, integrated circuit electronics, solid-state LCD display, and push-button switch selection. All VOM functions, plus the versatile diode test and high ohm-low ohm test functions, are standard. Each range has full auto-polarity operation and overrange indication. The meter uses the dual-slope integration measurement technique to insure noise-free measurements.

The unit is priced at $250 and comes complete with operator's manual, test leads, and built-in battery pack. For more information contact Elenco Electronics, Inc., 150 West Carpenter Avenue, Wheeling, Illinois 60090.

Circle #308 on Reader Service Card.

Callbook buys Radio School

Gordon West's Radio School has been purchased by Radio Amateur Callbook Inc. The Radio School is now part of the Callbook operation and the Callbook will handle all future order input and shipment of training courses and code tapes.

Gordon West will continue to develop additional upgrade training books and new code tapes.

Direct all orders and product inquiries to: Radio Amateur Callbook Inc., 925 Sherwood Drive, Box 247, Lake Bluff, Illinois 60044. Students needing to ask "Gordo" any questions

about training materials should write or call Gordon West, 2414 College Drive, Costa Mesa, California 92626, 714-549-5000.

Circle #309 on Reader Service Card.

Multi-pair audio "snake" cable

Belden Wire and Cable has a new line of multi-pair audio "snake" cables with individually jacketed and shielded pairs for protection against signal loss. These cables interconnect audio components.

The audio cable series offers eight different pair constructions ranging from 4- to 32-conductor pairs. Each is individually shielded with Beldfoil® for 100-percent coverage against interference. Jacketed with PVC and insulated with polypropylene, this series has 22 AWG (7 x 30) stranded tinned copper conductors. The loose tube construction enables high flexibility. Inner jacketed pairs are numbered for identification.

Available from stock in 100, 250, 500, and 1000-foot put-ups, this audio cable line is priced at $640 for 1000 feet of four-pair cable.

For more information or cable samples, contact Belden Wire and Cable, P.O. Box 1980, Richmond, Indiana, 47375.

Circle #310 on Reader Service Card.

RZ-1 wide-band scanning receiver

The RZ-1 wide-band, scanning receiver covers 500 kHz—905 MHz in AM, and narrow or wide-band FM. The automatic mode selection function makes listening easy. The receiver features one hundred memory channels with message and band marker, direct keyboard or VFO frequency entry, and scanning functions like memory channel and band scan — with four types of scan stop. The RZ-1 is a 12-volt DC-operated, compact unit, with built-in speaker, front-mounted phones jack, switchable AGC, squelch for narrow FM, illuminated keys, and a "beeper" to confirm keyboard operation. The suggested retail price of the RZ-1 is $599.95.

See your authorized Kenwood Amateur Radio dealer for more details, or contact Kenwood, 2201 E. Dominiquez Street, Long Beach, California 90810.

"Digalert" TNC message indicator

JComm has introduced an accessory for most popular TNCs to alert the operator visually if a message is waiting in the TNC's memory. This device plugs in series with your RS-232 cable with no modifications. When another station connects, an LED turns on and remains lit until you press the reset button on the front panel.

The "Digalert" is priced at $25. To order, or for more information, write to JComm, P.O. Box 5647, Boise, Idaho 83705.

Circle #311 on Reader Service Card.

Miniaturized gripper test connector

E-Z Hook has introduced the E-Z Micro Double Gripper Test Connector series.

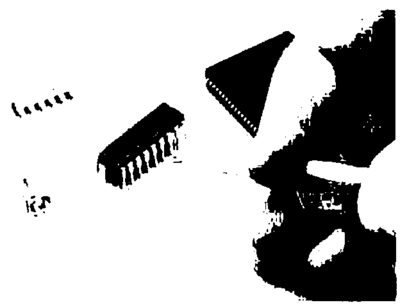
The Double Gripper XK series features a dual-contact blade assembly that opens and closes in a single extension step by depressing the unit's plunger. A gripping hook, built into the retractable stainless steel blades, provides secure, electrically continuous contact with the test object or other items. Both housing and plunger are molded of durable nylon.

The Double Gripper is 0.175" thick at its widest point. A probe-style tip, including the housing, measures only 2.125" long, and 0.525" high. The unit accepts 22 AWG test lead wire.

An assortment set of 10 individually color-coded XK Double Gripper units (part no. XK-S) is available, plus over 110 E-Z Micro Double Gripper Test Lead assemblies.

Complete specifications on the XK series, pricing, and all standard E-Z Hook products are available in a 112-page catalog. Contact E-Z Hook, Division Tektest, Inc., P.O. Box 450, 225 N. Second Avenue, Arcadia, California 91106-0450.

Circle #312 on Reader Service Card.



RC-1000 repeater controller

Micro Computer Concepts has introduced the RC-1000 — a complete repeater controller with on-board interfacing for the receiver/transmitter. It also features an autopatch with direct-connect phone line for pulse or touch tone dialing, a remote base or tape player, CW ID, and complete control and user touch-tone codes. Six pots allow for independent adjustment of all audio interfaces between the repeater receiver, transmitter, and phone line.

The heart of the RC-1000 is an Intel 8751 microcomputer containing 4K of EPROM, 128 bytes of RAM, and 32 programmable I/O pins. You can control the RC-1000 through the repeater receiver, or phone line callin. Touch-tone decoding is performed by a Mitel 8870 single-chip DTMF decoder.

The complete controller is contained on one 5.3" x 3.6" pc board. It requires 12 volts DC or AC, with separate inputs for a battery and transformer. Diode isolation is provided permitting direct connect of a battery with automatic switching when AC power is lost.

The RC-1000 comes wired and tested for $219.95. The price includes manuals and schematic. The unit is distributed by R&L Electronics, Hamilton, Ohio.

Circlo #313 on Reader Service Card.

High-speed 4800-baud modem

Hamilton and Area Packet Network (HAPN) has designed a plug-in 4800-baud modem for the TAPR TNC-1 and TNC-2 and many of its clones. This modem increases normal packet operation to four times the speed of the standard 1200-baud modem. Additional speed performance is achieved by a fast-acting modem squelch (about 15 mS).

The modem uses direct FM biphase modulation and doesn't require a randomizer or synchronization burst. There's no DC component in the encoded data, making it possible to use regular FM/PM synthesized or crystal-controlled voice radios. The required bandwidth is the same as for voice. The simple hookup to the radio's discriminator and modulator avoids the distortion normally caused by the mike preamplifier, limiter, emphasis, de-emphasis, and receive audio amplifier. Reliability is generally better than 1200-baud modems using the radio's mike and speaker connections. Radio voice operation isn't affected with the new interface installed.

The HAPN-T daughter board plugs into the external modem connector of the TNC. It's small size 9.5 ×7 cm (3.75 ×2.75 inches) allows it to be mounted inside almost any TNC. The power for the modem is taken from the + 12 volts inside the TNC.

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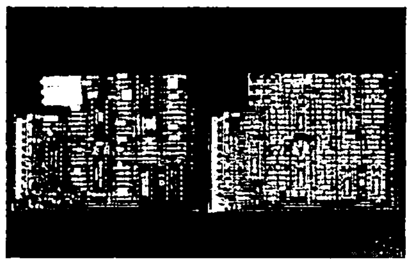
NEW products

The modem contains a multiplexer for switching between the 4800 HAPN-T and the 1200-baud modem on the TNC mother board. Detailed instructions are included for assembly and installation onto the TAPR TNC-1 and TNC-2 (and true clones, like MFJs).

The modem is available from HAPN in kit form. Write to: HAPN, Box 4466, Station D, Hamilton, Ontario, Canada, L8V4S7.

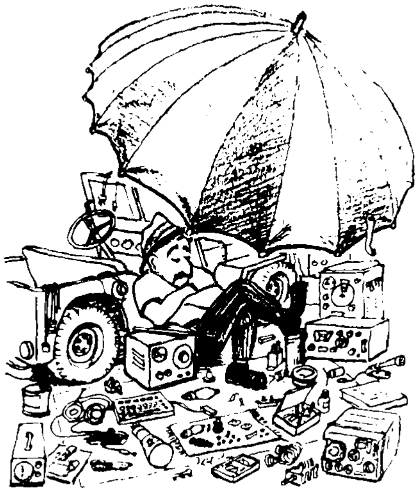
The cost of the bare board is $15 United States, $18 Canada. A parts kit containing the circuit board and components is $48 United States, $60 Canada. There is a 10-percent discount for orders of 5 or more units. Handling and shipping is $5 ($8 for overseas orders).

Circle #314 on Reader Service Card.



JANUARY WINNERS

Congratulations to Anthony Davis, N4SAS, our January sweeps winner and William Schreiber, NH6N, author of January's most popular WEEKENDER — "Going Digital." Both will receive a copy of *The Radio Handbook* by Bill Orr, W6SAI. To enter for February's drawing, send in the evaluation card bound into this issue, or submit a WEEKENDER project. You could be our next winner! *Ed.*



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HAMFESTS Sponsored by non-profit organizations receive one free Flea Market ad (subject to our editing) on a space available basis only. Repeat insertions of hamfest ads pay the non-commercial rate.

COPY No special layout or arrangements available. Material should be typewritten or clearly printed (**not** all capitals) and must include full name and address. We reserve the right to reject unsuitable copy. **Ham Radio** cannot check each advertiser and thus cannot be held responsible for claims made. Liability for correctness of material limited to corrected ad in next available issue.

DEADLINE 15th of second preceding month.

SEND MATERIAL TO: Flea Market, Ham Radio, Greenville, N. H. 03048.

BEGINNER'S RADIO CLEARINGHOUSE. On a space available basis, we are going to offer you, OUR SUBSCRIBER, free of charge, a chance to find a home for your used equipment with a new Ham. Please send us a short description of what you want to sell along with price, name, address and *phone number. We'll run it once in a special section of the* classified ads under the heading of BEGINNER'S RADIO CLEARINGHOUSE. Please limit your ad to 20 words or less.

YAESU FT-101E TRANSCEIVER. CW filter, fan, mint, $360. New 1989 Callbooks (postpaid USA): N.A. $23.50, International $25.50. Duane Heise, AA6EE, 16832 Whirlwind, Ramona, CA 92065. (619) 789-3674.

NATIONAL Radio Manual and NCL-2000 factory parts lists. SASE. Max Fuchs, 11 Plymouth Lane, Swampscott, MA 01907.

ELECTRONIC KITS & ASSEMBLIES. For our latest catalog send SASE (45 cents) to: A & A ENGINEERING, 2521 W. LaPalma, #K, Anaheim, CA 92801.

IBM-PC SOFTWARE FOR PK-232. New CompRity II/PK is the complete communications program for the PK-232/HK-232. Uses host mode of PK-232 for complete control. Text entry via built-in screen editor! Adjustable split screen display, including optional Triple Split ™ in Packet mode. Instant mode/speed change. Hardcopy, diskcopy, break-in buffer, select calling, text file transfer, customizable full screen logging, 24 programmable 1000 character messages, mailbox facility. Ideal for MARS and traffic handling. Requires 256k PC compatible. $65. Non-PK-232 version still available. Send call letters (including MARS) with order. David A. Rice, KC2HO, 144 N. Putt Corners Rd, New Paltz, NY 12561.

COMMODORE/AMIGA CHIPS (eg 6510-$12.55, 6526-$13.50, 6567-$19.95, 6581-$14.85, 82S100-$15.75, 901 ROM Series-$12.50), PARTS, DIAGNOSTICS, HARD TO FIND ITEMS. Authorized service center. Fast REPAIRS, low cost (eg. C64-$49.95 plus UPS). Heavy duty power supplies for the C64-$27.95 plus UPS. Kasara Microsystems (Division of QEP), Route 9W/Kay Fries Drive, Stony Point, NY 10980, 1-800-248-2983 (outside NY) or 914-942-2252.

ANTENNA PARTS CATALOG, LOWEST COSTS: Dipole/Quad/Ground Radial wire, insulators, center feeds, open wire feed line, coax, relays, (#14 multistrand dipole/quad wire, non-stretch, very flexible, $34 per 275' (minimum), $.12/ft. thereafter, includes shipping). Catalog: $2.00. DAVIS RF, PO Box 230-H, Carlisle, MA 01741. (508) 369-1738.

UHF PARTS. GaAs Fets, mmics, chip caps, feedthrus, teflon pcb, high Q trimmers. Moonbounce quality preamps. Electronic sequencer boards. Send SASE for complete list or call (313) 753-4581 evenings. MICROWAVE COMPONENTS, PO Box 1697, Taylor, MI 48180.

COMMODORE-128 PROGRAM available to track the Amateur Satellites. Uses Keperlian data supplied by NASA free. Tracks up to 8 satellites simultaneously. Program also supports printing schedules and predictions for satellites. Use it to track MIR and talk to the Cosmonauts. SATRAK128, $26.50 includes shipping. Other information on this or other programs for the C128, requires a business size SASE. Reid Bristor, WA4UPD, PO Box 0773, Melbourne, Florida 32936-0773.

WANT: 32S3 xmtr, 250TL and 304TL tubes. KF6WM, 45300 Royal, King City, CA 93930.

WANTED: Heath SB-220/1 mint cond. Jim, WA8CAJ (702) 827-3074.

$50 PACKET Digicom 64—software based PACKET system for Commodore 64. Software is public domain and requires a modem for the C64 which is provided by our kit. Board plugs directly into cassette port or remote mounted via cable, both connectors included. Watchdog timer, reed relay PTT and PTT inversion options included. Power derived from computer. Uses 7910 chip—no alignment required. Switch allows HF or VHF operation. Order Kit #154 for $49.95 or Assembly #154 for $79.95 both include FREE DISK. Add $2.50 s/h. A & A ENGINEERING, 2521 W. LaPalma #K, Anaheim, CA 92801. (714) 952-2114. MC or VISA accepted.

OFFICIAL MILITARY-TYPE ID TAGS. ("Dog Tags")!! Customized with your Call Letters, etc. 5 seventeen space lines. 20" nickel plated chain included. $4.29 postpaid. JPW ENTERPRISES, PO Box 353, Logan, Utah 84321.

MAGAZINES WANTED: "Microwave Systems News" (MSN), "RF Design", "PCIM (Power Conversion & Intelligent Motion)" and "QEX" (1980-present). Call collect 519-742-4594 (Ontario) after 6 PM Eastern time.

IMRA International Mission Radio Association helps missionaries. Equipment loaned. Weekday net, 14.280 MHz, 1-3 PM Eastern. Nine hundred Amateurs in 40 countries. Rev. Thomas Sable, S.J., University of Scranton, Scranton, PA 18510.

BACK ISSUES OF HAM RADIO. Have most issues from 1969 to 1974. Mint condition. $3.00 for single issues. WN0G, 319-377-3563.

FOR SALE: HW-101, TR-4, HT-37, 75A2, best offer. Want—Pair 8875 tubes. Tom Johnson, N6BP, 5060—500 Avenue West, Oak Harbor, WA 98277.

HAM TRADER YELLOW SHEETS. In our 27th year. Buy, swap, sell ham radio gear. Published twice a month. Ads quickly circulate—no long wait for results. Send No. 10 SASE for sample copy. $13 for one year (24 issues). PO Box 2057, Glen Ellyn, IL 60138-2057 or PO Box 15142, Dept HR, Seattle, WA 98115.

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CUSTOM MADE EMBROIDERED PATCHES. Any size, shape, colors. Five patch minimum. Free sample, prices and ordering information. HEIN SPECIALTIES, Inc., Dept 301, 4202 N. Drake, Chicago, IL 60618.

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RECONDITIONED TEST EQUIPMENT $1.25 for catalog. Walter, 2697 Nickel, San Pablo, CA 94806.

SCHOLARSHIP. The Dayton Amateur Radio Association is now accepting applications for its 1989 Scholarship Program. The program is open to any licensed Amateur graduating from high school in 1989. For information and application forms write Scholarship Committee, 317 Ernst Avenue, Dayton, OH 45405.

COMING EVENTS

Activities — "Places to go . . ."

SPECIAL REQUEST TO ALL AMATEUR RADIO PUBLICITY COORDINATORS: PLEASE INDICATE IN YOUR ANNOUNCEMENTS WHETHER OR NOT YOUR HAMFEST LOCATION, CLASSES, EXAMS, MEETINGS, FLEA MARKETS, ETC, ARE WHEELCHAIR ACCESSIBLE. THIS INFORMATION WOULD BE GREATLY APPRECIATED BY OUR BROTHER/SISTER HAMS WITH LIMITED PHYSICAL ABILITY.

NEW JERSEY: March 11. The Shore Points ARC's Springfest '89, Atlantic County 4-H Center, Rt 50, Egg Harbor City. Doors opn 9 AM. Sellers setup 7 AM. Admission buyers $3. Talk in on 146.385/.985 and 146.52. For information write SPARC, PO Box 142, Absecon, NJ 08201.

MICHIGAN: March 18. The 28th annual Michigan Crossroads Hamfest sponsored by the Michigan Amateur Radio Society and the Marshall High Photo Electronics Club, Marshall High School. 8 AM to 3 PM. Setup 6 AM. Tickets $3.00/door. $2/advance (SASE). Tables 50 cents/foot, minimum 4 ft. Reserved until 8 AM. SASE to SMARS, PO Box 934, Battle Creek, MI 49016 or call Wes Chaney, N8BDM (616) 979-3433.

NORTH CAROLINA: March 18-19. The Mecklenburg Amateur Radio Society is sponsoring the Charlotte Hamfest and Computerfair, ARRL Roanoke Division Convention, Charlotte Convention Center, 4th and College Streets, uptown Charlotte. Saturday 9-5, Sunday 9-2. Tickets $5/advance; $7/door. Children under 12 free. Flea market tables $12 advance only. Tickets and tables good for both days. Programs, forums, license exams, nearby parking and restaurants. For reservations and information write Charlotte Hamfest, PO Box 221136, Charlotte, NC 28222-1136.

TEXAS: March 18. The Midland ARC will hold its annual St. Patrick's Day Swapfest, Midland County Exhibit Building, east of Midland on north side of Hwy 80. 8 AM to 2:30 PM. Pre-registration $5, $6 at the door. Tables $6. each. License exams. For information and reservations Midland Amateur Radio Club, PO Box 4401, Midland, TX 79704.

ILLINOIS: March 19. The Libertyville and Mundelein Amateur Radio Society (LAMARS) will hold its annual LAMARSFEST 1989 at the Lake County Fairgrounds Rts 120 and 45. Large indoor electronic and radio swapfest, exhibitors, rest area, free parking, public cafeteria. Admission $2/advance; $3/door. Swap tables $5. Commercial tables $20 by reservation only. Doors open 8 AM. Setup 6 AM. Talk in on 147.63/03 Waukegan repeater and 146.52. For information write LAMARS, PO Box 751, Libertyville, IL 60048 of call Bob Dick, NY9E (312) 362-9634 after 7 PM.

OHIO: March 19. The Toledo Mobile Radio Assn's Hamfest, Lucas County Recreation Center, Key Street, Maumee. 8 AM to 5 PM. Admisison $3.50/advance; $4/door. Talk in on 147.27 repeater or 442.85 repeater. Contact: Ron Morris, WB8ZIM, 28141 Glenwood Rd, Perrysburg, OH 43551 (419) 666-8063.

KENTUCKY: March 25. Kentucky State ARRL Convention sponsored by the Lincoln Trail ARC. Pritchard Community Center, Elizabethtown. Admission $4/advance; $5/door. For advance tickets, setup reservations and exam info contact Chuck Strain, AA4ZD, PO Box 342, Vine Grove, KY 40175. (502) 351-1715.

MISSOURI: March 31-April 2. The PHD ARA will sponsor the 1989 Midwest ARRL Convention, Kansas City Convention Center, 13 and Broadway. Exhibits 9-5 Saturday and Sunday. Setups

3-8 PM Friday. DX, QCWA, Packet, Computers, ATV, ARRL, FCC and more. Exams 8 AM Sunday. No walkins. Large indoor flea market tables $10. Pre-registration $5. $7 at the door. Saturday evening banquet $13.50. All pre-registrations must be postmarked by March 20, 1989. Mail to PHD ARA, PO Box 11, Liberty, MO 64068. Phone (816) 781-7313. SASE for confirmation or information.

NEW JERSEY: April 8. Ham Radio flea Market sponsored by the Chestnut Ridge Radio Club, Education Building, Saddle River Reformed Church, East Saddle River Road and Weiss Road, Upper Saddle River. Tables $10 for first, $5 each additional. Tailgating $5. Admission $1. Contact Jack Meagher, W2EHD (201) 768-8360.

INDIANA: April 8. The Columbus Amateur Radio Club Hamfest. Bartholomew County 4-H Fairgrounds, State Road 11, Columbus. 8 AM to 2 PM. Talk in on 146.79 -600 Hz. For information David Mann, KA9UUP, 458N Country Club Road, Columbus, IN 47201. (812) 342-6302.

WISCONSIN: April 9. The Madison Area Repeater Association (MARA) is having its 17th annual Madison Swapfest, Dane County Exposition Center Forum Building, Madison. Doors open 7 AM for flea market sellers and 8AM for general public. Admission $3 advance, $4/door. Under age 12 admitted free. Flea market tables $8 advance; $9/door plus admission. Advance reservations by March 31, 1989. Talk in on MARA repeater WE9AER/R, 147.75/.15. For tables or info on commercial space write MARA, PO Box 4007, Madison, WI 53711 (608) 274-5153 day or night.

MASSACHUSETTS: April 9. The Framingham Amateur Radio Assn will hold its annual Spring Flea Market and License exams, Framingham Civic League Building, 214 Concord Street (Rt 126) in downtown Framingham. EARLY BIRD BUYERS doors open at 9 AM. Admission $5.00. ALL OTHER BUYERS doors open 10 AM. Admission $2.00. Tables $12, setup time 8:30 AM. Preregistration for flea market and exams is required. Talk in on 147.75/15 Framingham Repeater. For information and table reservations contact Jon Weiner, K1VVC, 52 Overlook Drive, Framingham, MA 01701. (508) 877-7166. For license exams send Form 610, copy of license and $4.65 check payable to ARRL/VEC, Framingham ARA, PO Box 3005, Framingham, MA 01701.

NEW JERSEY: April 15. "Flemington Hamfest 89", sponsored by the Cherryville Repeater Association, 8 AM in the Hunterdon Central High School Field House. Admission: $4 advance, $5 door. Children under 12 and XYLs free. Refreshments available from 6:30 AM. Advance tickets: Dave Hickson, KD2RC, 125 South Main St, Lambertville, NJ 08530. Tables: Marty Grozinski, NS2K, 6 Kirkbridge Rd, Flemington, NJ 08822. Information: (201) 788-4080 before 11 PM EST. VE testing begins at 10 AM, send FCC form 610, photocopy of current license, and a check for $4.75 (payable ARRL/VEC) to: Cherryville Repeater Association, VE Test Team, Box 308, Quakertown, NJ 08868. Talk in: 146.52, 147.975/375, 145.615/015, 222.52/224.12 and 449.85/444.85 MHz.

ILLINOIS: April 16. The Moultrie Amateur Radio Klub's 26th annual Hamfest, Moultrie County 4-H Grounds, Cadwell Road, 4 miles east of Sullivan. Gates open 7 AM. Tickets $3; 2/$5. Large covered outdoor area available FCFS. No charge for vendors. Food available. For information Ralph Zancha, WC9V (217) 873-5287 or write MARK, PO Box 79, Sullivan, IL 61911.

DAYTON HAMVENTION: April 28, 29, 30.

OHIO: April 28. The 4th annual DX Dinner, Dayton Hamvention Weekend, sponsored by the SouthWest Ohio DX Association, Stouffer's Dayton Plaza Hotel. Cash bar 6:30 PM; dinner at 7 PM. Keynote speaker Dave Heil, J52US. Master of Ceremonies Frank Schwab, W8OK. Banquet $22.00 per person by reservation only. Please SASE along with check or MO payable to SWODXA to Scott Lehman, N9AG, PO Box 803, Greenville, OH 45331.

OHIO: April 29. The 20th annual B*A*S*H will be held on Friday night of the Hamvention at the Conference Center (Madison Room) of the HARA Arena and Conference Center, same location as the Hamvention, starting at 7 PM. No admission charge. Free continuous entertainment. Hot dinner, sandwichs, snacks and beverages are available. Two exciting top awards and many others. Stay right at HARA when the Hamvention closes on Friday evening and meet your friends and join us for an evening of fun and entertainment. Sponsored by the Miami Valley FM Association, PO Box 263, Dayton, Ohio 45401.

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NORTH COAST ARC 1989 LICENSE EXAMS. 12:30 PM, Saturdays February 11, April 15, June 10, August 12, October 14, December 9. N. Olmsted Community Cabin, S of Lorain on W. Park. Novice thru Extra. Walkins allowed. Talk in 145.29 repeater. For information Dan Sarama, KB8A, 15591 Rademaker Blvd, Brookpark, Ohio 44142. 267-5083 or Pauline Wells, KA8FOE, Rick Wells, K8SCI, 777-9460/779-8999.

AMATEUR RADIO CLASSES: For those people interested in obtaining a Novice (basic level) Ham license or upgrading to Tech/General, the Chelsea Civil Defense, in cooperation with QRA Radio Club, will sponsor Amateur Radio Communications classes evenings at Chelsea High School starting MARCH 7, 1989. For more information write Frank Masucci, K1BPN, 136 Grove Street, Chelsea, MA 02150. Please enclose your telephone number.

THE MIT UHF REPEATER ASSOCIATION and the MIT Radio Society offer monthly HAM EXAMS. All classes Novice to Extra. Wednesday, MARCH 22, 7 PM, MIT Room 1-150, 77 Mass Avenue, Cambridge, MA. Reservations requested 2 days in advance. Contact Ron Hoffmann at (617) 484-2098. Exam fee $4.50. Bring a copy of your current license (if any), two forms of picture ID, and a completed form 610 available from the FCC in Quincy, MA (617) 770-4023.

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CORRECTION

ILLINOIS: March 12. The Sterling-Rock Falls ARS 29th annual Hamfest, Sterling High School Field House, 1608 Fourth Avenue, Sterling. Doors open 7:30 AM. Tickets $3/advance; $4/door. Dealers, large flea market, VE exams. Talk in on 146.25/146.85 W9MEP Repeater. For information, tables or tickets contact Sue Peters, P.O. Box 521, Sterling, IL 61081 or call AC (815) 625-9262.

ELMER's NOTEBOOK

Tom McMullen, W1SL

Packet radio for the first-timer

I came up with the subject for this month's column after overhearing comments and conversations at some recent hamfests. It was apparent that quite a few Amateurs would like to explore packet (and other digital modes), but are a bit puzzled about what to do after buying the equipment and plugging it in. After all, it's slightly more complex than getting started with a CW rig where you hook all the pieces together, tap out a CQ on the key, and listen for a reply. A first-time venture into the phone bands is not all that difficult either. A "hello" into a microphone will often bring back a surprising "hello yourself" from the receiver, or perhaps a "QRZed?" Once you get to this point, establishing a QSO isn't hard at all.

Many people are easily intimidated by computers, and connecting one to a transceiver can make "mike fright" or a "frozen fist" seem insignificant. The first step is to get on good terms with your computer. No matter what make it is, learn to use the built-in features: how to save files to a hard drive or a floppy diskette, what to do when it says "syntax error," and how to recover from the inevitable "dead-keyboard" experience — when the little cursor just blinks at you or, even more unsettling, the screen stays blank! But these procedures are more properly addressed in the realm of an article or book on computer operations, and this column is about Amateur Radio, so let's direct our attention to making the packet radio system do its thing.

For almost all packet systems, you need a "communications" or "terminal" program for your computer. Many of the common ones available will work — I've used QModem, PC-Talk, Bitcomm, PC-Pakratt, and Powercomm 12 on my PC/AT. My favorite is Procomm because it's the one I've used the most for checking into bulletin boards and data services via the telephone line and a modem. Use whatever program you're comfortable with; the goal is to have your computer talk to the outside world.

The next step is to establish communications with your packet equipment, the Terminal Node Controller (TNC). This is the interface between your computer and the radio equipment. It contains all the "smarts" to accept what you type on the keyboard and turn it into a message complete with headers, addresses, error-checking methods, etc. It also works in the reverse — deciphering a received packet of information and turning it into words to display on your screen.

There are many variations of the commands used in packet systems and it would be impossible to describe all of them here. Look at the instruction manual for your particular TNC and make a list of the commands you're most likely to use at the beginning, based on those described here.

The TNC I now use is the PK-232 by AEA. I used to have a TNC-1 from the Tucson Amateur Packet Radio Corporation (TAPR). TAPR has come out with a TNC-2, but I haven't tried it. Some commands are the same for the PK-232 and the TNC-1; some are not. The PK-232 has a very large set of commands covering everything from calibrating the system to switching from VHF to HF or from packet to AMTOR or RTTY. You'll need only eight or ten commands to start having fun on this mode.

Your first words

The first thing that you should see when your computer and the TNC start talking to each other is a message of some sort. It will probably give you a copyright notice, the date the program was released, and perhaps some other information as well. The greeting should be followed by the letters **cmd:** (a prompt, asking you for a command or instructions).

Before going further, you need to know that the TNC has two modes of operation — the command mode where it's waiting for instructions and where it responds to those instructions, and the converse mode where it will interact with another station by receiving and sending packets. When you see the **cmd:** (or **CMD:**) prompt, the TNC expects some instructions from you. Please note: most TNCs don't care whether you use upper or lower case. I'll use lower case for our purposes.

If you haven't already done so, now is the time to tell the TNC who you are. You do this by typing **mycall** or just **my** and then hitting the return or enter key, whichever you have. (Some keyboards have a symbol like a backwards letter L with an arrowhead. They all do the same thing.)

Most TNCs will accept either the

entire command or a one- or two-letter abbreviation. The monitor will show a statement, like **mycall aaa**, in answer to what you just typed. You can then respond with **mycall** (type your call here) and return. Your call is now stored in memory and will be used whenever a packet is sent or received. The call stays in memory even when the equipment is turned off, so you don't need to repeat this step the next time you use it.

The command mode

In addition to letting you give instructions, the command mode will let you find out all kinds of things about your terminal. Just type **display** (or **disp**) followed by a letter or number at the **cmd:** prompt. For example, **cmd:disp L** will fill your screen with the link status information. You won't use much of it for most operation, but it's there when you want it. At the moment, the statement you're looking for is that link status is disconnected (meaning that you are not connected to another station).

Another useful display is the monitor parameters. Here you can see what the monitor function is doing. (This is the monitor activity of your terminal, *not* the video-display screen you are looking at.) Typing **comd:disp m** will give you a screen full of monitor settings. Among these the **mfrom** setting is important because it determines what on-air activity you'll see on your screen. Three other commands very useful for a beginner are: **help**, **connect**, and **disconnect**.

Here's an important tip: If things get so confused that you're not sure what's going on, and you don't see the **cmd:** prompt, you can always get back to the prompt by holding down the control key and the C key at the same time (sometimes written in text as <control-C> or <^C>. This puts the system back in the command mode, and you can start over.

Try the **help** command **(cmd:help)** just to get familiar with what's available. After you've made a few dozen contacts you'll know all about the system anyway, but for now it's nice to know that it can help you out. It's reassuring to know that most terminals will let you know when they don't understand something. For instance, if I type **connet** when I mean **connect**, the system replies with **?what?**

After you've entered your call into the machinery and looked at the help screen for reassurance, try monitoring some activity. Make sure your transceiver is tuned to a packet frequency, and that there's something going on. You'll have to tell the terminal what you want to monitor. On some TNCs, you do this by typing **monitor all**, **monall**, **mall**, or **mall on**. For the PK-232, the command is **mfrom**. If you just type **mfrom**, the TNC will tell you its current setting; if it says **mfrom none** you won't see any activity. Type **mfrom all** and you'll see what's happening — including packets between two stations, packets being relayed, or announcements (beacons) from local bulletin-board stations. Later on, you can become more selective and give your TNC a list of the calls you want to monitor by typing **mfrom yes**. (List the calls, separated by a comma.) You can also shut out calls by typing **mfrom no** (call or calls).

The connection

After you've monitored the activity for a while, try a contact. Note the call of someone who has just disconnected (or sent a CQ packet), and type in **connect** (type in his call) and hit return. You could try this with a bulletin board, but if you do, be prepared for a screen full of announcements and/or questions about who you are and whether you'd like to sign up as a member, etc. If the station you picked is available, your screen should show **connected to** (his call). At this point, almost all TNCs go into the converse mode automatically. This means you can carry on a two-way QSO with the station you're connected to. Just type away — ask questions, talk about the weather, your rig, the family, or whatever.

Remember that what you type isn't sent to the other guy until you do a return. The return key is the computer's way of saying "over" on voice, or sending "K" on CW. (Standard practice on packet is to send three > > > symbols at the end of your last line of text to indicate "over".) You'll also see what the other station sends, but be patient. Some people are not high-speed typists, and typing two or three lines one-finger style can take a couple of minutes.

Via who?

You'll see some activity that has "via" or "v" in the list of callsigns, as in **connect WW4HAO via WW4DA**. This means they are connected through a digipeater. Some stations append a number after their call to help identify them as a digipeater, like WW4DA-2. Type in the station you want to connect with, the word **via** (or the letter **v** if your program can use that abbreviation), then the call of the digipeater (including the number, if any) and hit return. Once you've established a connection, you don't need to tell the terminal to use the digipeater each time — it will remember to do so until you end the contact.

Ending the contact? Just typing "bye" or "73" or "see-ya-later" won't hack it. That will tell the other guy you're all through, but you also have to tell your terminal. It's easy to do. Just type **disconnect**, **disc**, or simply **D** at the **cmd:** prompt. (You get back to **cmd:** by using control-C.) Your terminal will respond with **disconnected**. If the other station decides to quit first, and sends the disconnect command, your terminal will tell you that he has disconnected.

Another useful feature is the list of stations heard. It lets you get a feel for the activity in your area. On the PK-232 the command for this is **mheard**. The terminal will list the last 18 calls heard, and those heard directly (not through a repeater) will be marked with an asterisk (*). You can find out the times stations were on by typing **daystamp on** when you start up your station. The list will then include the time and date of each call shown.

Confusion factors

There are many things about this new mode that can leave a newcomer bewildered, wondering what went wrong and why. One is the lack of response when a **connect** request doesn't produce any results. Overlooking the possibility that the other station just shut down or told his terminal to ignore any more connect requests for the evening, a lack of response could be caused by collisions between packets (two stations trying to send at the same time). This doesn't happen often, but probably will as channels become more crowded. One thing you can do is find out the number of times your station will try before it gives up. Check the setting by typing **retry** at the **cmd**: prompt. The terminal should reply with a number, e.g., **retry 10**. You can change this by typing **retry** followed by any number from 0 to 15. **Retry 15** means your station will try 15 times before giving up and showing the message **retry count exceeded**. You can also change the amount of time between retries. The PK-232 does this by using the **frack** (frame acknowledge) command. For local stations, a low number like 2 or 3 seconds should be okay (**frack 3**). If you're working through one or more digipeaters, use a larger number to allow time for the packet to be handled by the relay stations. You can specify a number up to 15 seconds, but it should be a compromise between how long you are willing to wait and what produces the most success in your area.

The timing between sending and receiving is a critical part of packet operation. Your TNC is capable of switching from transmit to receive in a few milliseconds, but your RF transceiver is not. Obviously, if the other station acknowledges the packet before your receiver is ready, you'll never make a contact, and vice versa. Modern diode-switched send/receive circuits are pretty good, but still require considerable switching time. Most transceivers that use relays for send/receive switching will require longer delays than solid-state equipment. This delay can be set from the **cmd:** prompt. The time is usually given in milliseconds — e.g., 500 = 500 milliseconds or 0.5 seconds. Start with some value around 600 mS (**cmd:dwait 600** for the PK-232), and try to connect to a local station. You can then lower the number to find a value that works well with your station.

Packet radio is a well-established, growing communications mode. There are linking and network developments on the way that will be very exciting to explore. So dive in — don't let keyboard fright deprive you of a lot of very enjoyable QSOs.

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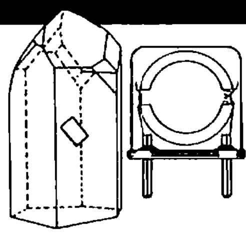

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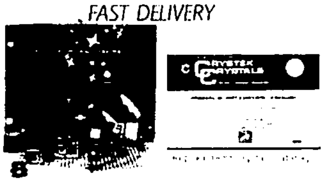

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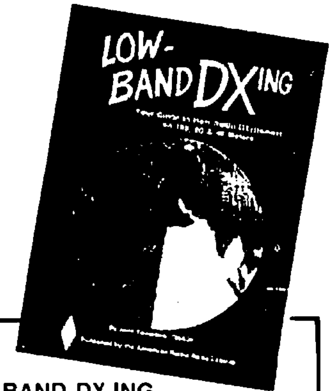

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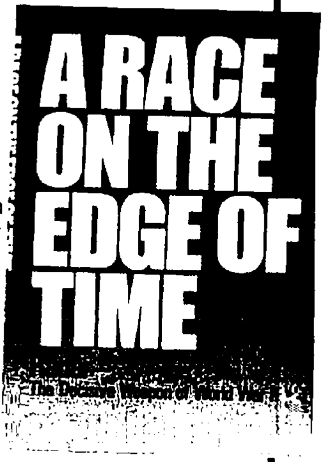
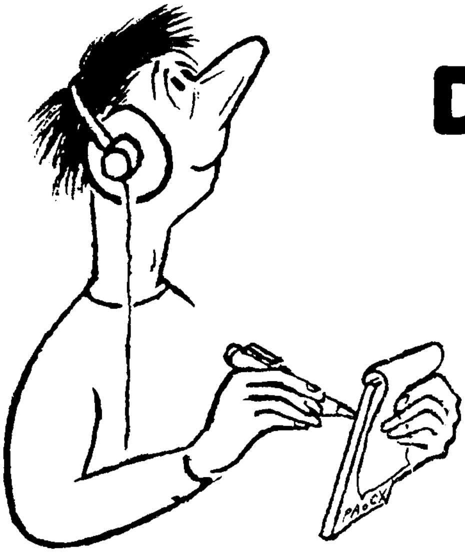


A RACE ON THE EDGE OF TIME

AMATEUR RADIO
LOG



DX FORECASTER

Gerth Stonehocker, KØRYW

Equinox DX conditions

March and April, the months of the spring equinox, show rapidly changing DX propagation conditions. One change is the increase in daylight hours. Also during these months geophysically unstable day-to-day phenomena are very noticeable. Weather storms come and go quickly across our skies, and you'll have nights and/or days of poor radio propagation conditions. Because DX propagation is so variable, you might try keeping up with these changes scientifically, or forecasting the DX conditions for a few hours or days. One forecasting system is based on two geophysical daily indices that are useful for predicting trends. These indices are the solar flux daily index and geomagnetic field disturbances.

The solar flux daily index is a measure of the radiated solar energy coming to earth. It's used to determine the electron density of the ionosphere during these rapidly changing months. There's about a 5-percent change between summer and winter (winter is the maximum). This year the 22nd sunspot cycle is the largest change affecting the solar flux. But remember the most rapid time of seasonal change (5 percent) is during the equinox months. The range of maximum usable frequencies in the E and F regions and signal absorption in the D region vary directly with the sun's radiation, as measured by the solar flux.

Rapid solar flux changes aren't the only cause of unstable propagation conditions in the mid- to high latitudes. Geomagnetic field disturbances also cause variable propagation conditions. These disturbances to the basic trend of the solar flux are short lived; they average two days if flare induced, and a day or two longer if due to coronal thinness. Either way, they are caused by particles flowing from the sun as solar wind. The wind enters the earth's atmosphere in the polar regions — around 80 degrees on the sunward side. As the particles enter the D and E regions, they decrease the signal strength and cause flutter, fading, and even total signal disappearance. Later during the night at lower latitudes (sometimes down to around 60 degrees) the F region becomes depleted, lowering the MUF there.

Both of these indices (geomagnetic and flux) are broadcast from radio frequency and time station WWV at 18 minutes after each hour. By keeping track of the daily values and noting the trend, you can forecast by extrapolation the continued direction of DX propagation conditions — both signal strength and MUFs. Increased solar flux means an immediate signal strength decrease, but within a day or two there will be increased MUFs with the potential for higher signals. For DX, increased geomagnetic A or K means decreased and variable signal strength and MUFs. On paths near the equator the MUFs rise with an increasing A index. You can try this forecasting method for your favorite DX path, or for DX conditions in general.

Last-minute forecast

March propagation conditions should mirror February's, as the 27-day solar rotation cycle is the most influential predictor available in this part of the 11-year sunspot cycle and it coincides with February's 28-day length. Expect the first 10 days of the month to favor the higher frequency bands with high MUFs and signal absorption from a solar flux maximum. Long skip with some chance for transequatorial openings should be available to southern countries. The lower bands will be most favorable for nighttime openings to northern and east-west countries from the 16th to the 24th. The solar flux is expected to climb after this date. Disturbed conditions may affect the bands near March 2nd, 10th, 19th, and 29th.

No regular meteor showers occur in March. The full moon is on the 22rd and its perigee is on the 8th. The vernal equinox is on March 20st at 1539 UTC. A partial (0.83 percent) solar eclipse is expected on the 7th from 1617 to 1958 UTC. It will be visible in Hawaii, the United States, Canada, and Greenland.

Band-by-band summary

Ten meters will be open to the south and southeast for an hour before local noon, to the south at noon, and to the southwest in the afternoon. The openings will be longer when the solar flux is at its 27-day cycle maximum. Transequatorial openings will also be best at that time.

Fifteen, 17, and 20 meters, almost always open to some part of the world, will be the main daytime DX bands. Twenty should stay open on long southern paths into the night, while 15 will drop out in the late afternoon. DX is 5000 to 7000 miles (8000-11200 km)

MARCH

WESTERN USA

GMT	PST	N ASIA FAR EAST	NE EUROPE	E S. AFRICA	SE S. AMERICA	S ANTARCTICA	SW NEW ZEALAND	W OCEANIA AUSTRALIA	NW JAPAN
0000	4:00	15	30	15	10	10	10	10	12*
0100	5:00	15*	30	15	10	10	10	10	12
0200	6:00	15*	*30*	15	12	12	10	10	12
0300	7:00	15	*30*	20	12	12	10	10	15
0400	8:00	20	*30*	*20*	12	12	12	10	15
0500	9:00	20	*30*	*20*	15	15	12	12	20
0600	10:00	30	30	20	15	15	15	12	20
0700	11:00	30	30	*20*	*20*	20	15	12	30
0800	12:00	30	*30*	*20*	*20*	20	15	15	30
0900	1:00	30	*30*	*20*	*20*	*20*	20	15	30
1000	2:00	*30*	*30*	*20*	*20*	*20*	*20*	15	30
1100	3:00	*30*	*30*	*20*	*20*	*20*	*20*	*20*	30
1200	4:00	*30*	20	15	*20*	*30*	*20*	*20*	*30*
1300	5:00	*30*	15	12	15	*30*	*20*	*20*	*30*
1400	6:00	30	15	10	15	*30*	*20*	*20*	*30*
1500	7:00	30	12	10	12	15	*20*	*15*	30
1600	8:00	30	12	10	12	15	15	*20*	*30*
1700	9:00	30	12	10	10	12	15	*20*	*30*
1800	10:00	30	15	10	10	12	12	*20*	*30*
1900	11:00	*30*	15	10	10	12	12	15	20
2000	12:00	*30*	20	12	10	10	12	15	15
2100	1:00	*30*	20	12	10	10	10	12	15
2200	2:00	*30*	30	12	10	10	10	12	12
2300	3:00	20	30	15	10	10	10	12	12*

MID USA

MST	N ASIA FAR EAST	NE EUROPE	E S. AFRICA	SE S. AMERICA	S ANTARCTICA	SW NEW ZEALAND	W OCEANIA AUSTRALIA	NW JAPAN	CST
5:00	20	30	15	10	10	10	10	12	6:00
6:00	15	30	15	10	10	10	10	12	7:00
7:00	20	30	15	12	12	10	10	15	8:00
8:00	30	*30*	*20*	12	12	12	10	15	9:00
9:00	30	*30*	*20*	12	12	12	12	20	10:00
10:00	30	*30*	*20*	15	15	15	15	20	11:00
11:00	30	*30*	*20*	15	15	15	15	20	12:00
12:00	30	30	*20*	*20*	20	15	15	30	1:00
1:00	*30*	*30*	*20*	*20*	*20*	20	15	30	2:00
2:00	*30*	*30*	*20*	*20*	*20*	*20*	*20*	*30*	3:00
3:00	*30*	*30*	15	*20*	*20*	*20*	*20*	*30*	4:00
4:00	20	20	12	*20*	*20*	*20*	*20*	*30*	5:00
5:00	20	20	12	*20*	*20*	*20*	*20*	*30*	6:00
6:00	15*	20	10	15	*30*	*20*	*20*	30	7:00
7:00	15	15	10	15	15	*20*	15	30	8:00
8:00	20	15	10	12	15	20	15	30	9:00
9:00	30	12	10	12	15	20	*20*	*30*	10:00
10:00	30	12	10	12	15	15	*20*	*30*	11:00
11:00	30	15	10	10	12	15	15	*30*	12:00
12:00	30	15	10	10	12	12	15	20	1:00
1:00	*30*	20	12	10	12	12	15	15	2:00
2:00	*30*	20	12	10	10	10	12	15	3:00
3:00	*30*	30	12	10	10	10	12	12	4:00
4:00	*30*	30	15	10	10	10	10	12	5:00

EASTERN USA

EST	N ASIA FAR EAST	NE EUROPE	E S. AFRICA	SE CARIBBEAN S. AMERICA	S ANTARCTICA	SW NEW ZEALAND	W OCEANIA AUSTRALIA	NW JAPAN
7:00	20	30	15	10	10	10	10	15
8:00	30	30	15	12	10	12	10	20
9:00	30	30	15	12	12	15	10	20
10:00	30	30	*20*	12	12	15	12	30
11:00	30	*30*	*20*	15	12	20	15	30
12:00	30	*30*	*20*	15	15	20	15	30
1:00	30	*30*	*20*	15	15	20	15	30
2:00	*30*	*30*	*20*	*20*	*20*	20	*20*	*30*
3:00	*30*	*30*	*20*	*20*	*20*	*20*	*20*	*30*
4:00	20	*30*	20	*20*	*20*	*20*	*20*	*30*
5:00	15*	20	12	*20*	*20*	*20*	*20*	*30*
6:00	15	20	12	*20*	*20*	*20*	*20*	30
7:00	15	20	10	15	*20*	*20*	15	30
8:00	20	20	10	15	15	20	15	30
9:00	20	15	10	12	15	20	15	30
10:00	30	15	10	12	15	*20*	15	30
11:00	30	15	10	12	15	*20*	*20*	*30*
12:00	30	15	10	10	12	15	*20*	*30*
1:00	30	15	10	10	12	15	*20*	*30*
2:00	30	15	10	10	12	12	15	20
3:00	*30*	20	10	10	12	12	12	15
4:00	*30*	20	12	10	10	10	12	12
5:00	*30*	30	12	10	10	10	10	12
6:00	*30*	30	15	10	10	10	10	12

The italicized numbers signify the bands to try during the transition and early morning hours, while the standard type provides MUF during "normal" hours.

*Look at next higher band for possible openings.

on these bands and one-long-hop transequatorial propagation is also possible, as on 10 meters.

Thirty and 40 meters are both day and night bands. Intermediate distances (1000-1500 miles, 1500-2200 km) in any direction represent daytime DX. Nighttime DX on these bands may be expected to offer a greater distance than on 80 meters and, like 80, to follow the darkness path across the sky. Reduced midday signal strengths and distances may occur on days of high solar flux values.

Eighty and 160 meters will exhibit short-skip conditions during daylight hours and lengthen for DX at dusk. These bands follow the darkness path, opening to the east just before local sunset, swinging more to the south near midnight, and ending up in the Pacific areas shortly before dawn. The 160-meter band opens later and ends earlier.

Article M **HAM RADIO**

(continued from page 6)

in Honolulu from 1934 to 1939 and was acquainted with Kenneth Lum King. He lived just a few blocks from where I lived for a time. I worked him while he was with the expedition on one of the Islands. I find in my log of November 21, 1935 at 4:45 PM Honolulu time that I took a message from him and phoned it to its destination. I also noted that the signal was very wobbly. As I recall, I had to keep turning my dial most of the time to copy him as he drifted too.

The mention of the China Clipper brings back memories. The day that it first arrived in Honolulu, I was camped with a group of school boys at Lailua on the beach and we heard on the radio that the Clipper was nearing the Island. We ran out on the beach and looked off to the east, and low on the horizon we could see this big four-engine airplane coming in. It had a letter on it for me from a girlfriend in California, and it was delivered a day or so later. When the Clipper was to return to San Francisco, I along with many others went out to Pearl Harbor to see it take off.

Walter M. Bolinger, N6UX,
K6BUX in 1935,
Keene, Texas 76059

Parts kit available from author

Dear HR

Thanks for publishing my article, "A Simple Low-cost Comb Generator Frequency Calibrator," in the July 1988 issue of your magazine.

I have received quite a bit of mail requesting parts for the project. I have therefore put together a complete kit of parts for $39.95 plus shipping and taxes. Individual parts are priced separately.

Could you please communicate this information to your readers?

Larry R. Martin, PO Box 997,
Sebastopol, California 95472

Consider it done! Ed.

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volume 22, number 4

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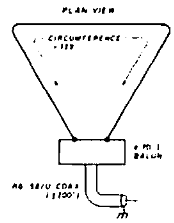
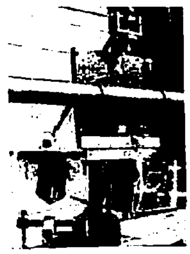


W6SAI, page 55

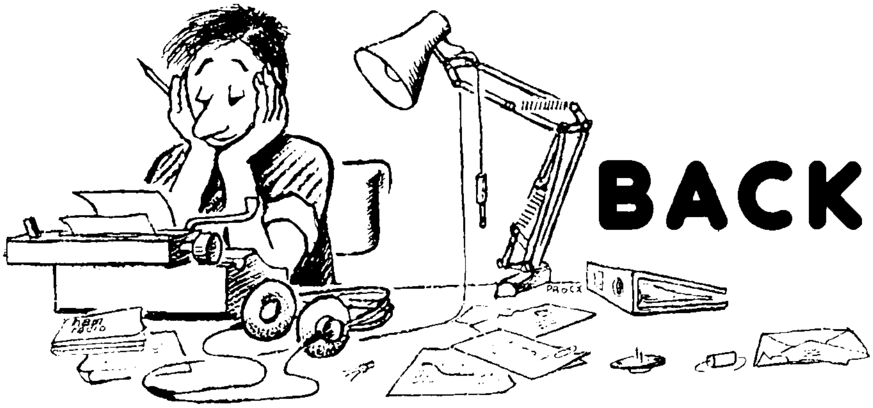


NH6N, page 79

NU1N, page 18
WA9HUV, page 65

See page 74 for the winners of February's Weekender contest.

DEPARTMENTS



BACKSCATTER

Changes...1989 update

Close to a year ago, we set out to make *Ham Radio* the number one magazine in the Amateur Radio field. It's been a long, difficult process fraught with pitfalls and setbacks, but we are well on our way.

It will take time to reach our goal, but we can do it with your help. The children's story "The Little Engine That Could" reflects HR's aspirations. The competition is tough. We know we must work very hard at tailoring the magazine's content to please you. That's why we've been asking you, our readers, what you think of our changes. The responses to our reader surveys and evaluation cards have been outstanding. Over 95 percent of you approve of what we've been doing. To be fair, there are those of you who aren't happy. We hope that in time, we can win you over too!

To our effort to serve you, we pay strict attention to all reader comments. In the past two years, your letters to us have asked for MORE PROJECTS and CONSTRUCTION please! And so we began the process of redirecting HR to fill your needs in that area. This process isn't easy. As many of you already know or are learning, it's often difficult to get parts. It's also difficult to get authors to write about their construction projects. We do feel that we have an excellent group of authors writing for us now, but there's always room for more.

HR is a reflection of you, our reader. While a significant number of you are technically oriented and look to HR for electronic information, you're also Hams — men and women who take their love of radio and communications home every night. Some of you do little but tinker and test. Others are "die-hard" contesters who can't wait for the next major event. Some of you bemoan the departure of tubes. Others are immersed in the latest digital state-of-the-art electronics. In short, your interests run from Alpha to Omega.

When Jim Fisk, W1DTY and Skip Tenney, W1NLB, started *Ham Radio* in 1967, their goal was to mail a magazine that stayed away from politics and delivered nothing but the best in technical Amateur Radio subjects. During it's first ten years, HR met that goal. Unfortunately, Jim's untimely death in 1980 upset the formula and it's taken us a few years to get back on track. Under Rich Rosen's, K2RR, guidance HR once again re-established itself as the Amateur's technical magazine. Now Marty Durham, NB1H, Bob Wilson, WA1TKH, and Terry Northup, KA1STC, are working very hard to ensure HR includes only the very best technical articles every month.

Our new look, created by local graphic artist Ann Desmarais, is designed to make HR more readable. While consistency is safe, a design change was necessary. HR looked like it was locked in a 1968 time warp. The new logo is a bold statement of HR's commitment to quality. The inside layout is clean and easy to read. The type was selected to compliment the text and other material, not fight it. The page layout was modified to take maximum advantage of the space on each page. The only complaint we've received about our graphics changes is that some of you find them too drastic, too bold. The bars over the figures are distracting to a few readers. Others have told us they find the bars help them locate and identify figures and schematics. We'll keep working to refine these changes to meet your needs.

So what's the bottom line? You've asked us to not become a clone of the other magazines. HR has met that goal. By staying in our niche of construction and projects, HR can continue to deliver what you want. But we need and want your comments. Write, call, look us up at Hamfests — TALK to us! Keep letting us know what you like and dislike. This is your magazine. Tell us how can we make it better for ***YOU***!

Craig Clark, N1ACH

COMMENTS

Another satisfied customer

Dear HR

I just received January, 1989 — a superior piece of work that is as good as any you have ever published. The article mix had something for most enthusiasts (HF synthesizer, 3456-MHz through ATV) and the articles had some guts. Not everyone is going to run out and build Dave's (WA3JUF) 3456 rig, but almost everyone reading an article like that is bound to at least learn something new. Nice job by John Shelley, WA1IAO on ATV — get some more pieces like that out of him.

As difficult as it is to avoid the standard cliches, keep that kind of material coming. Could be your best issue ever — I have them all.

John W. Molnar, WA3ETD, Milford, New Hampshire 03055

Points to ponder

Dear HR

I'd like to make a few observations. First, even though the "Short Circuit" (page 35, October issue) does appear at the end of an article in the series to which the correction applies, it would be a thoughtful touch to include the information reference on the "Contents" page. This is of future help when your memory says there was one, but you don't remember where for certain.

I note an apparent shift to computer program coverage relating to the "clones." There is usually a statement or at least an inference that no great problem should exist in converting BASIC programs to other machines, and this is probably true. However, in view of the popularity of the C-64 in the ham fraternity, would it not be thoughtful to include an already "converted" C-64 version?

Thanks for listening.

John E. Runninger, WB2LCP, Rome, New York 13440

Gremlins?

Dear HR

A gremlin somehow must have snuck into The Weekender column "Get the Most From Your NiCads" (December 1988). The caption for Photo A is on Photo C; Photo B's caption is on Photo A; and Photo C's caption is on Photo B. Otherwise it was a very interesting article!

Bill Wornham, WA1CRE, Townsend, Massachusetts 01469

Information for all

Dear HR

I wish to congratulate you on the improvement of your *Ham Radio* articles this past year. They are more informative for the new hams as well as the older ones.

I am not going to single out any writer, but I feel the articles for the younger hams are important these days too and I think some of the other ham magazines have forgotten this fact.

I want to draw your attention to the odd article that should have been checked for accuracy or edited.

Keep up the good work.

E. W. Forster, Blaine, Washington 98230

Great February Cover

Dear HR

The February *Ham Radio* cover was great. Haven't seen anything like it since the days of Phil Gildersleeve and Clyde Darr of early QST days...

Congrats!

Bruce Kelley, W2ICE, American Wireless Association, Inc., Holcomb, New York 14469

The last hurrah

Dear HR:

It isn't often one hears a ham on the air performing outstanding services for other hams. I know of one who gives of himself tirelessly, without letting up; without regard to his personal health or equipment he's steadfastly at his key, carrying out his mission. Most surely, the deity had called upon him to fulfill his destiny at the controls of his station.

It happened early one January morning around 1300 GMT on 7005 kHz during the Mellish Reef DXpedition operation. His signal was strong and his fist rang out in flawless CW, "UP 5..UP 5!" And occasionally, to remind us of our humble beginnings in radio, he would embellish, "UP 5..UP 5 LID!" Oh, if only to have had him for an Elmer in another time. I could tell he was becoming fatigued; this monumental task was taking its toll. His timing became ragged and he was not coming down on his key precisely when the DX operator started sending, resulting in many operators being able to hear Mellish Reef coming back to their call. I knew he wouldn't be able to keep up the frantic pace. It was kind of like the death throes of Kipling's Gunga Din, the immortal regimental bugler. In a last hurrah of "UP 5..UP 5", with tongue lolling, finals red hot, his hand slipped off the key and his signal drifted off.

Seldom can we pay tribute to such an operator, an enduring essence of QRM, virtually a pure flux of Hertzian generated disturbance. Wherever you are, out there in the QSB, here's to you, "traffic cop!" You're a better man than I am!

Don Longacre, NW2V Caledonia, New York 14423

BUILDING A DIGITAL FILTER

FIR filter features guaranteed phase linearity

By Paul Selwa, NB9K, 61 East Tilden Drive, Brownsburg, Indiana 46112

Digital filters provide high-performance designs with properties that can't be provided by analog filters. These properties include: stability, no tweaking, repeatability, insensitivity to temperature, and the guaranteed linear phase response of Finite Impulse Response (FIR) filters. This last characteristic is required in narrow bandpass filters for phase-shift encoded digital data like that used on the Mode-S transponder in the Phase 3C satellite.

Digital filters aren't new, but it's only recently that the inexpensive ICs needed to build them have become available. The main hardware impediment has been the lack of low-cost digital multipliers. In software, the problem has been the lack of inexpensive programs to determine the filter's coefficients. Optimal filter designs require extensive iterations and aren't practical for manual calculation.

This article provides information about the construction of FIR digital filters. You can construct the hardware if you have a general knowledge of digital techniques. I can provide you with a program which calculates the coefficients for FIR filters of up to 128 taps.

FIR filters

There are various types of digital filters; the FIR filter is the most useful. This filter is unconditionally stable and has guaranteed linear phase response. It's resistant to the effects of noise, because any noise components are in the filter only until a new set of data samples has been taken. It's also the type of digital filter least sensitive to the effects of the precision (length) of the filter coefficients.

IIR filters

The other popular digital filter is the Infinite Impulse Response (IIR) filter. Because a portion of an IIR filter's output is fed back into the filter, any disturbance at the output is partially present in all subsequent outputs until the filter is deliberately cleared and the process is repeated. Another concern with IIR filters is their highly nonlinear phase response. For phase-dependent modes of communication, like phase-shift encoded data in digital transmission, the data may be garbled and no subsequent filtering will completely remove the distortion.

FIR filter construction

A FIR filter consists of the following sections:

- A low-pass filter (LPF) limits the bandwidth of the signal. This is called an anti-aliasing filter.
- An analog-to-digital converter (ADC). It may need to be preceded by a sample-and-hold circuit if its conversion time is long.
- A data memory that saves the digitized samples of the signal. Data is often saved in two's complement (2C) form for compatibility with hardware multipliers.
- A set of filter coefficients that are used to multiply the data memory's samples. These are often called filter taps and are usually stored in 2C form.
- An accumulator that contains the sum-of-product terms that are generated by multiplying the data memory contents by the filter's coefficients.
- A multiplier chip, or a processor with multiplying capability. Multiplier accumulators (MACs) are common.
- A digital-to-analog converter (DAC) to change the filter's digital output word to an analog signal.
- A low-pass filter to remove clock noise from the DAC's output. It is called a reconstruction filter and has the same bandwidth as the anti-aliasing filter.
- A controller to coordinate the actions of these pieces of hardware. It can be as simple as a PROM, containing control bits with a counter to read out the PROM's words sequentially, or it can be an actual digital signal processor like the Texas Instruments TMS32010 with its own program.

You can build a compact system, like the TI-based system shown in fig. 1, with a few LSI chips. This version requires an assembled program for the TMS32010 processor. The coefficients are in the program PROM and the data memory is on the processor chip. The anti-aliasing filter, the ADC, the DAC, and the reconstruction filter are in the TLC32040.

A more efficient implementation for home assembly consists of two GE chips made for FIR applications. The ISP9128 is a FIR controller and the ISP9210 is a MAC. These two chips do most of the work for you. The approximate cost of this pair is $80.

Aliasing

Any digital filter has a bandwidth limitation that's set by the sampling rate of the input ADC. To prevent aliasing, the sampling frequency must be at least twice the bandwidth of the anti-aliasing filter. The folding frequency is defined as exactly one-half the sampling rate and is theoretically the maximum frequency that the filter can handle without aliasing problems. This frequency is often referred to as the Nyquist frequency or rate. It's called the folding frequency because the sampler's output frequency components have mirror symmetry around that frequency.

When a signal is being sampled at a given rate, the signal's components are duplicated above and below each harmonic of the sampling frequency, just as they would appear as sidebands of AM transmitters operating at those frequencies.

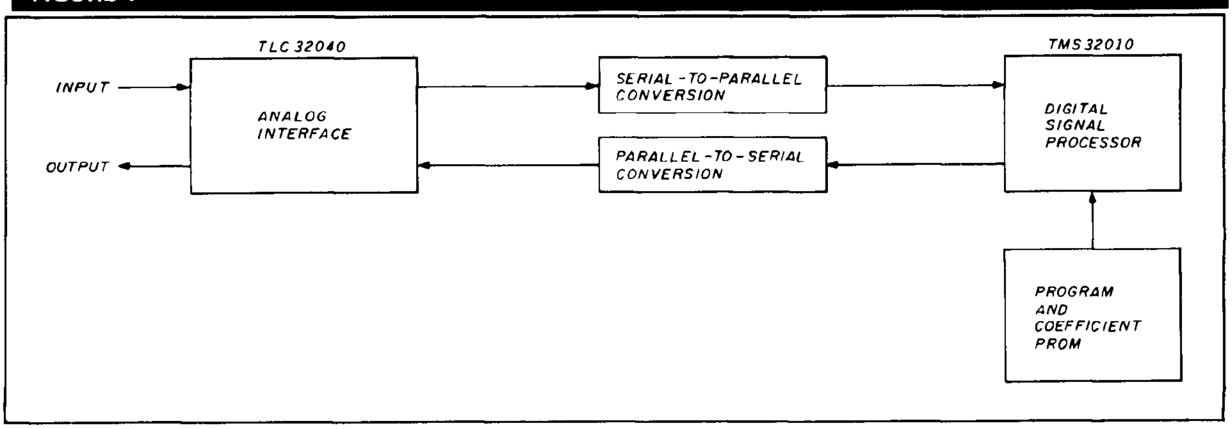
The only one you need to worry about is the fundamental sampling frequency. If you have a sampling rate of 10,000 Hz and a signal of 1000 Hz you'd get spurious outputs from the sampler at 9000 Hz (10,000 – 1000 Hz) and at 11,000 Hz (10,000 + 1000 Hz), in addition to the baseband signal of 1000 Hz. If you raised the input signal's frequency to 4999 Hz, the sampler would produce sideband components at 5001 Hz and at 14,999 Hz, and also preserve the 4999-Hz baseband signal. At an input frequency of 5000 Hz you'd be unable to distinguish between the real signal and the sideband of 5000 Hz (10,000 – 5000 Hz) from the sampling signal's carrier. As you further increase the input frequency, the lower sideband copy of the input signal takes on the alias of a lower frequency input signal. That's why the LPF precedes the ADC.

Anti-aliasing filters

These filters can be passive or active. While the theoretical cut-off frequency of the LPF can be at the folding frequency, any practical filter has finite rolloff. You can't get away with using a sampling rate that's barely twice the highest frequency component you pass through the LPF. Practical anti-aliasing filters have cut-off frequencies of approximately one-third the sampling rate, so the LPF's response will be down 40 dB or more at the folding frequency. For voice communications that require bandwidths of 2500 Hz, you'll see sampling rates of 8000 Hz or greater. For other modes, like CW which needs no more than 1000-Hz response, you can get away with a sampling frequency of 3000 to 5000 Hz.

A poor choice of anti-aliasing filter can upset your FIR system's operation. If you depend on the inherent linear phase response of the FIR structure, use a linear phase (flat group delay) LPF for anti-aliasing and for the reconstruction filter. An easy way to obtain flat group delay is to use the EXAR XR-1003/1004 — a switched-capacitor low-pass Bessel filter. These filters preserve the information in phase-shift encoded data. Another advantage of using switched-capacitor filters is that you can divide the sampling clock to drive the LPF and you'll automatically be in the correct ratio with respect to the sampling rate. That may not be important in a system using a single sampling rate, but for a dynamically reconfigurable system you won't have to worry that the anti-aliasing LPF is at the wrong bandwidth.

FIGURE 1

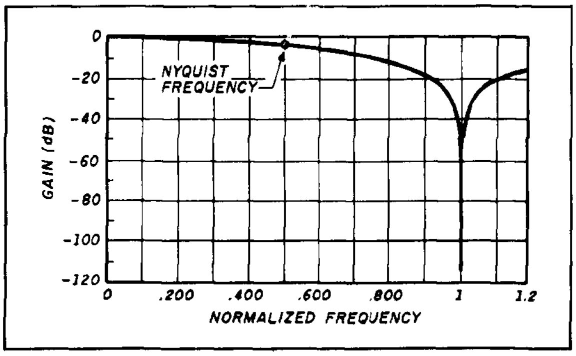


One-chip digital signal processor implementation.

ADC

The ADC is one of the simpler system blocks, but distortion is introduced in the converted number — called the (sin X)/X error — where X = pi • input frequency/sampling frequency. The ratio (sin X)/X is equal to 1 for X = 0 (DC signal), and gradually drops to zero when the input frequency is equal to the sampling frequency. The loss at the Nyquist frequency is 3.9 dB, as shown in **fig. 2**. For normal communications work, the relative reponse across the audio band is of little importance; you can ignore this factor without a problem. This is especially true if the sampling rate is high with respect to the anti-aliasing filter's cutoff, because the loss from the (sin X)/X rolloff is small. You can obtain a first-order correction by pre-emphasizing the input signal to the ADC.

FIGURE 2



Sin(X)/X response. Note the Nyquist Frequency is shown at 0.5 on this scale.

Filter coefficients

The stored data samples *are all* multiplied one-for-one by their corresponding filter coefficients, between the acquisition of each successive data sample. The product of each multiplying operation is accumulated and the resulting sum-of-products is a data word that's output by the filter, until the next output value is calculated.

The FIR design program calculates filter-coefficient sets for up to 128 tap filters. Depending on the sampling rate you choose, you may not be able to do all the multiply accumulate (MAC) cycles between two successive data samples. This means you'll either have to shorten the filter's length or build faster MAC hardware. The design program allows a total of five bands including stopbands plus passbands. The fancier the filter's operation, the longer the time for the filter to define these bands. You'll need fast hardware for the most elaborate types of filters. But it's easy to build the low-pass, single bandpass, notch, and high-pass filters with moderate filter time length.

The program first calculates a coefficient set for a filter having unity gain (zero dB). While these tap weights will produce a working filter, the number set may not use your system's full 8 or 16-bit capability unless it can handle floating point math. After locating the tap weights for the zero-dB filter, the program finds the largest value coeffient and scales them all linearly to gain the best use of fixed-point hardware's mathematical range. For example, the largest coefficient might not require the most significant 2 bits in the system. In that case, you'd get one-fourth the signal level from the filter that the hardware is capable of producing. The scaling process results in a filter with the same frequency response, but with something other than zero-dB gain. The gain figure is printed in the output listing, just ahead of the scaled tap values. In this example the scaled filter would have 12-dB gain.

The results are printed in floating point decimal and in fractional 2C hexadecimal. If you don't want to use the entire 16 bits of the hex coefficients, simply start at the highest (left-most) bit and use the number of bits you want. This 2C notation is used almost universally in computers and in MAC hardware. The 2C part refers to the technique used to encode bipolar binary numbers in which the most significant bit of the number is the sign bit (0 = plus, 1 = minus). The "fractional" part refers to the fact that the total of the remaining bits have a positive value less than 1. This number approaches unity more closely as the length of the 2C number increases. The value of a 2C tap from this filter program will be equal to:

− 1 • (sign bit) + (positive value of the remaining bits) with the left-most remaining bit having a value of + 0.5, the next having a value of + 0.25, and so on.

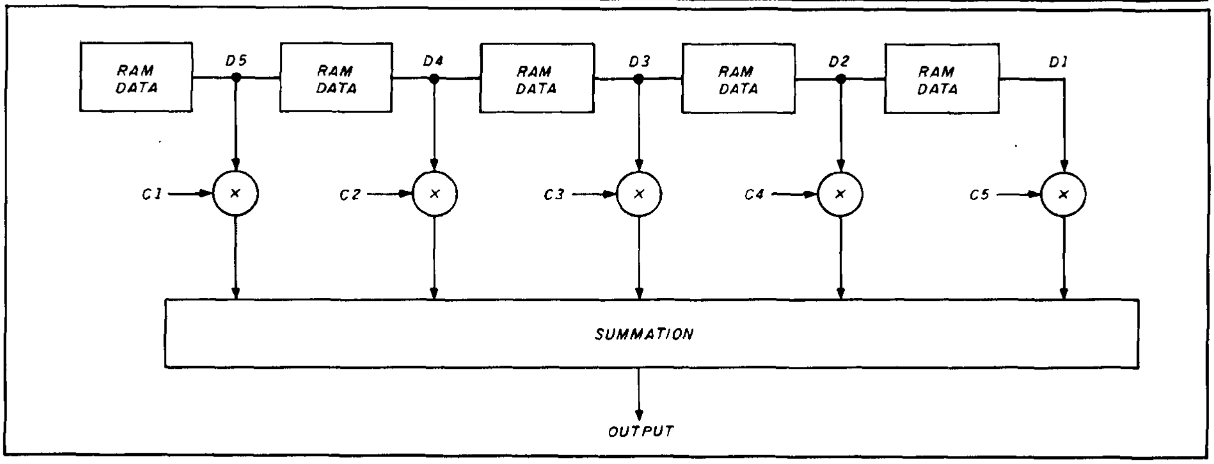
FIR filter operation

Suppose you need a length 5 FIR filter. The program will calculate the filter's coefficients, which are symmetrical around the center value (the third in this case). If you've chosen an even number of coefficients the symmetry will still exist, but without a unique central value. The coefficients are labeled in the program's output and must be used in sequence. In this example, the data memory will be length 5. It will always be the same length as the number of taps in the digital filter. The five most recent data samples will be multiplied by the five coefficients as shown in **eqn. 1**. To make notation easy, I'll refer to the data samples as D1-Dx, to the coefficients as C(1)-C(5), and to the outputs as O1-Ox (see **fig. 3**). The first usable filter output is produced after the fifth data sample is taken.

$$O1 = D1 \cdot C(5) + D2 \cdot C(4) + D3 \cdot C(3) + D4 \cdot C(2) + D5 \cdot C(1) \qquad (1)$$

The output value O1 is placed in the output DAC. Calculation stops until the sixth data sample appears. It replaces the sample D1 (i.e., the oldest sample) and then calculates the second output. In all cases, the new data sample replaces the oldest stored data sample.

FIGURE 3



Filter state for output 1.

$$O2 = D2 \cdot C(5) + D3 \cdot C(4) + D4 \cdot C(3) + D5 \cdot C(2) + D6 \cdot C(1) \qquad (2)$$

Output sample O2 is placed into the output DAC. Again the filter waits for the next data sample (which replaces sample D2), then calculates the third output sample.

$$O3 = D3 \cdot C(5) + D4 \cdot C(4) + D5 \cdot C(3) + D6 \cdot C(2) + D7 \cdot C(1). \qquad (3)$$

This process is continued, and the filter produces outputs at the same rate as the incoming samples. Note that the filter operates on the most recent data samples only (five in this example), and the older ones are written over in the data memory as more recent samples are taken. No portion of a noisy data sample remains in the filter; the FIR structure, compared with an IIR filter, is insensitive to noise. The process of shifting the data relative to the coefficients doesn't have to be an actual data shift in memory. You can accomplish the same effect by using counters as data pointers to place new samples and to retrieve the samples for the MAC operation.

Output data

The multiplication of two signed 16-bit words produces a 32-bit product in which two identical sign bits appear. Take the top 16 bits as your result, after you perform a left shift of one position to remove the redundant sign bit. Some multiplier chips automatically perform this function. Many times, the accumulator used in building an output value has more than 16 bits of resolution (like our example). Thus an intermediate value that exceeds its 16-bit capacity wouldn't cause overflow and a false result by a "wraparound" from the maximum number, past zero, to a smaller number. When the total sum-of-products is finished for a given output sample, some product terms may have been negative and some positive; this helps prevent overflow. Any filter can be overloaded, so scale your inputs properly to avoid problems.

You may have to change the 2C result back into simple binary code for the output DAC. Do this by inverting the sign bit position of the sum-of-products. This shifts the 2C number to a value between zero and the maximum value your data variable can achieve.

Controlling the filter

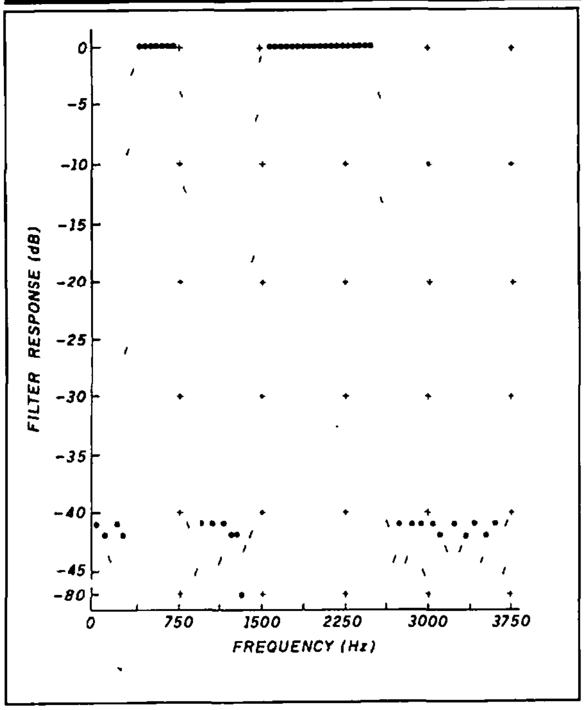
If the filter is built of separate pieces instead of a FIR controller chip or a one-chip digital signal processor with its own program, you'll have to generate the control program in a PROM or use some other method to produce a "state machine." This is a little tedious, but not difficult. You must determine how many separate bits are needed to drive the control inputs for the ADC, data RAM, coefficient PROM, MULTIPLIER, DAC and other elements of the system. The PROM data readout will be sequential, because a counter will be used to drive the address inputs of the chip. At each new address, you'll program 1 bits to perform the control functions required at that time interval. As the counter runs through its range, the logic signals to control the various parts of the filter will be read out. To avoid problems from address or data skew, use a register at the PROM data outputs to clean up the data. This will cause a one-clock cycle delay in the filter activity, but that's no problem. The first two locations in the PROM can be all zeros to get everything set up. Think of the bits as a method of defining sequential events, without consideration of active high or active low control states. Make all bits represent active high events inside the PROM; if you need an active low output, invert the bit outside the PROM. This technique is less prone to error than if the PROM contents directly

create both high and low active logic. In practice, this method takes several PROMs operating in parallel to create enough control bits.

Using the FIR design program

After the program starts, it prompts you for a file name so it can store the filter's parameters on disk. Entries are made in an interactive mode. The file includes all your entries, and all numeric and graphic outputs. There's a compressed graph to give you an idea of the filter's response curve. This curve covers one CRT screen, with a vertical scale of 5 dB per line. A detailed graph in 1-dB steps is also available. A portion of a sample problem output is shown in **fig.** 4.

FIGURE 4



Frequency response of the 5-band sample problem.

Sample problem

As an example of the type of filter you can build, consider a filter of length 128, which passes the first three voice formants. The bands are defined as 0-250, 375-700, 825-1400, 1525-2500, and 2625-3750 Hz. The sampling rate is 7500 Hz. The maximum of the stopband response is below −40 dB, with the deepest notch reaching −80 dB. The numeric outputs and stopband data below −45 dB are deleted to compress the figure.

A smaller version of this program is available from Public Brand Software, Inc., P.O. Box 51315, Indianapolis, Indiana 46251. This version, on their disk HR11.0, will create filters of maximum length 10. The full-featured version is available only from the author, for $45.00. (Indiana residents add 5-percent state sales tax.)

Parts sources for FIR filters

Texas Instruments parts
TMS32010NL
TLC32040NL
General Electric parts
ISP9128CP64
ISP9210CP6465
EXAR parts
XR-1003CP
XR-1004CP
Parts Suppliers
TI and EXAR parts can be obtained from Marshall Industries. Call 1-800-522-0084 for the nearest location.
GE parts can be obtained from:
Hamilton Avnet Electronics
485 Gradle Drive
Carmel, Indiana 46032
(317)844-9333

Article A **HAM RADIO**

THE WEEKENDER

Easy antenna access for urban apartment dwellers

By Bryan Bergeron, NU1N, 30 Gardner Road, Apartment 1G, Brookline, Massachusetts 02146

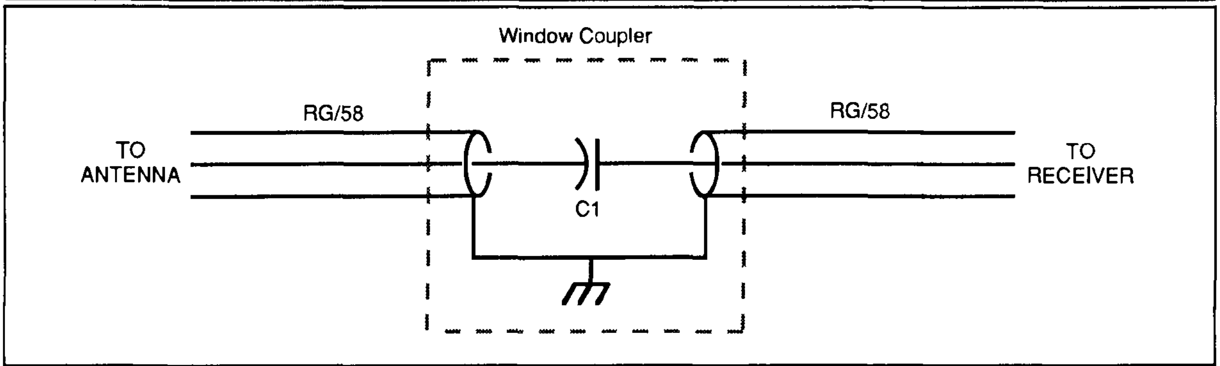
This article is dedicated to those urban HF operators who, because of security or other restrictions, have been unable to have constant access to a good receiving antenna.

My typical operating procedure on the HF bands is to listen to the activity on each band, then attach the appropriate loading coil to a loaded vertical antenna mounted on a pipe on my balcony. Sometimes I simply want to hear the latest solar activity forecast on WWV or catch the news from the BBC. Because I live in an apartment building with brick walls and aluminum-framed windows, this operation normally requires several trips through a sliding-glass door that leads to the balcony. Blasts of cold air entering my small apartment are side effects in the winter.

Confronted with this dilemma (and complaints from my XYL), I sought a solution that would eliminate the outdoor excursions for *receive only* applications or at least limit the ones required to begin HF operation. The most direct solution, drilling holes in either the brick wall or an aluminum window frame for a coaxial feedthrough, isn't allowed by my landlord.

I tried using a window antenna, but the it proved unsatisfactory. It was impossible to secure the window properly against burglars with the antenna installed. Anyway, the antenna I tried is designed for wooden window frames, and must be insulated from an aluminum window mount. I tried using a block of wood drilled to accommodate coaxial cable and wedged in the window frame, but this also resulted in an unacceptable security risk. Because of my location on the ground floor and the construction of the apartment building (an effective Faraday shield!), an indoor antenna proved useless — even for WWV reception.

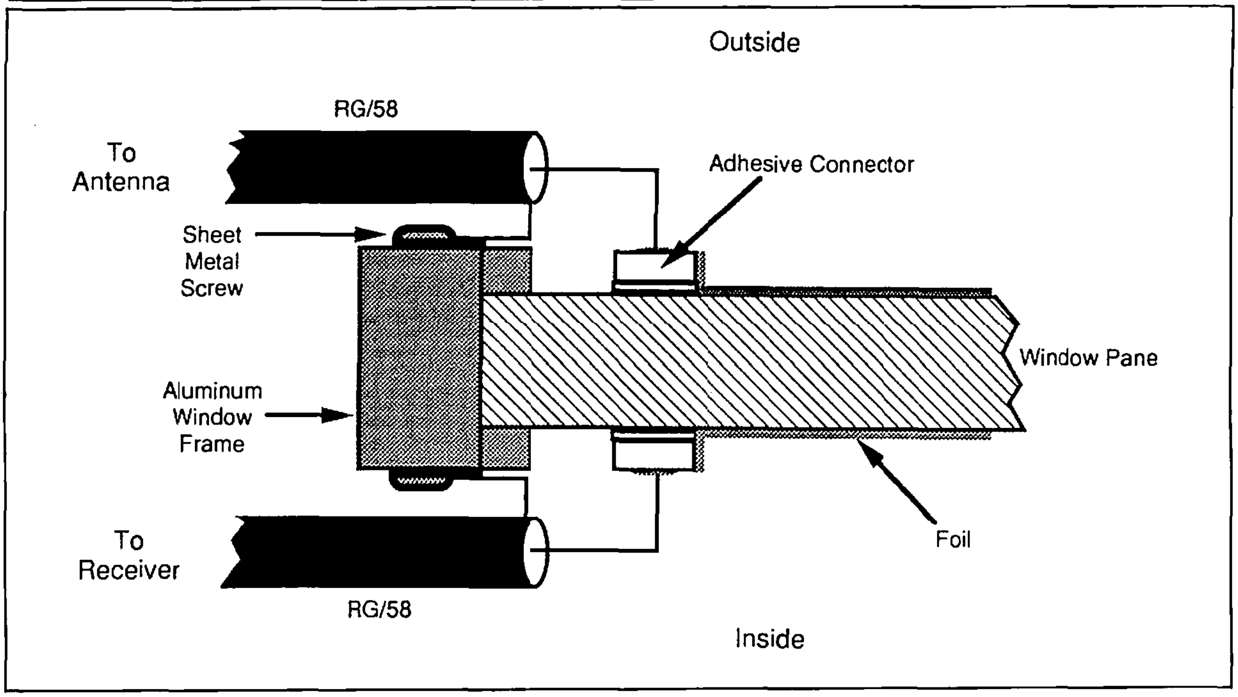
FIGURE 1



Schematic diagram of the window coupler. An effective RF connection is provided through coupling capacitor C1.

It occurred to me that I might try coupling RF from an external antenna through my window, adapting a method similar to those used in some mobile window-mount VHF antennas. The schematic in **fig. 1** shows the basic concept involved in what I call the "window coupler." The coaxial cable from my receiver (an ICOM R-71A) is connected, through coupling capacitor C1, to an external coaxial cable that feeds a "stealth" dipole antenna. The window cross section in **fig. 2** shows the details of the window coupler. Notice that coupling capacitor C1 is formed by two strips of aluminum foil mounted exactly opposite each other, on either side of and along the width of the window. The single-pane glass of the window forms the dielectric of C1. The two parallel foil strips, each 3/8″ × 48″, form the capacitor's plates. The braids of both the internal and external coaxial cables are connected to

FIGURE 2



Window cross-section showing the details of coupling capacitor construction. The center conductor of each coaxial cable is connected to parallel foil strips with the aid of adhesive connectors designed for connecting the foil to burglar alarm systems. The braids of each cable are connected to the aluminum window frame.

Parts list

Adhesive-backed foil—Radio Shack part no. 49-502 (120 foot roll—$5.99)

Adhesive connectors—Radio Shack part no. 49-504 (3 pair for $2.59)

Krylon Acrylic Spray Coating, Crystal Clear no. 1301 (about $3)

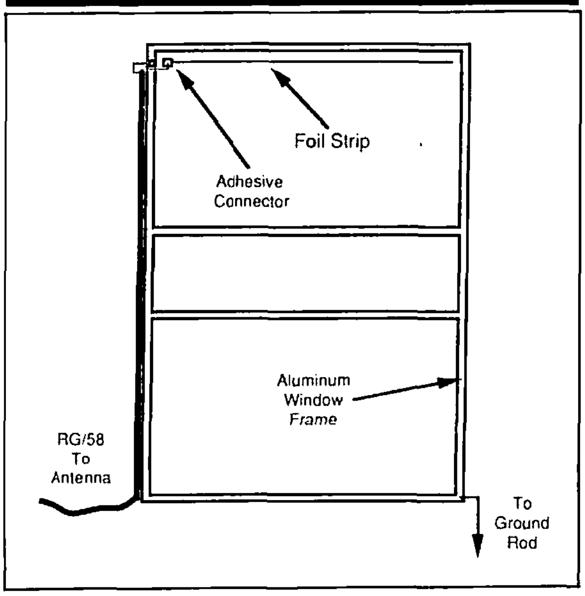
Silicone sealer

the aluminum window frame by the existing sheet metal screws. The frame is grounded through a short length of coaxial braid connected directly to a 6-foot copper ground rod (see **fig. 3**).

Both the adhesive-backed aluminum foil and adhesive-backed connectors used for building the coupling capacitor are available from Radio Shack. Adhesive foil and connectors, designed orginally for burglar alarm systems, make for a quick and aesthetically pleasing installation (see **fig. 3**). To keep the outside connections clean and free of corrosion, make sure that you cover the coaxial connection with a small amount of silicone sealer. To prevent the foil from deteriorating, I sprayed the outside strip with a thin layer of clear acrylic spray coating. Clear fingernail polish or clear enamel will work as well.

The window coupler performs magnificently as a means of providing a connection to an external receive antenna. There's no detectable degradation in received signal strength on the HF bands when using it, com-

FIGURE 3



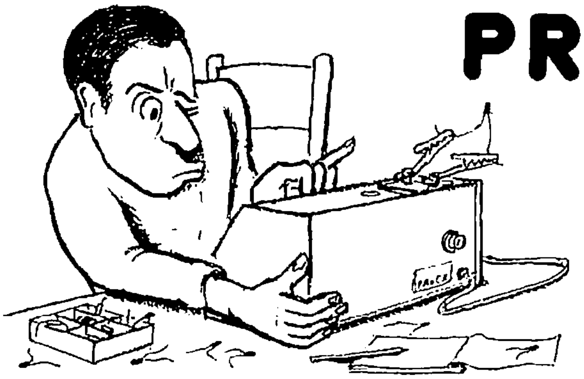
The window coupler as seen from the outside. The foil strip along the top edge of the window provides for an inconspicuous installation.

pared with a direct connection to my dipole antenna. Now I have constant access to WWV and the shortwave bands. I can listen for band openings at the wee hours of the morning or late at night without disturbing my family, compromising the security of our apartment, or incurring the wrath of my landlord.

Now the obvious question: Is the window coupler any good for transmission? Well, I've made several contacts through the coupler with a QRP rig (an HW-8) on 15 meters. With an MFJ-900 Transmatch and a long-wire antenna attached immediately to the outside foil strip, I've been able to achieve an SWR ratio of less than 1.3:1 across the CW segment of the 15-meter band. Because the foil strips are so thin, I haven't tried to transmit through the window coupler with my Swan 500 — for fear of vaporizing the aluminum foil! For high-power applications, you might want to try extending the strip in an "L" shape, or use several strips in parallel.

I hope that you enjoy this simple and easy to build window coupler. Let me know if you have any questions and/or enjoy using the system.

Article B **HAM RADIO**



PRACTICALLY SPEAKING

Joe Carr, K4IPV

Light metal and other topics

The oscilloscope (shown in **photo A**) is an instrument that lets you examine a waveform appearing on the screen of its cathode ray tube (CRT). Most of you are aware of the oscilloscope's usefulness in examining low-frequency waveforms, but you may not know that the instrument is also helpful at RF frequencies. At one time, most oscilloscopes were limited to frequency responses of 500 kHz or less.

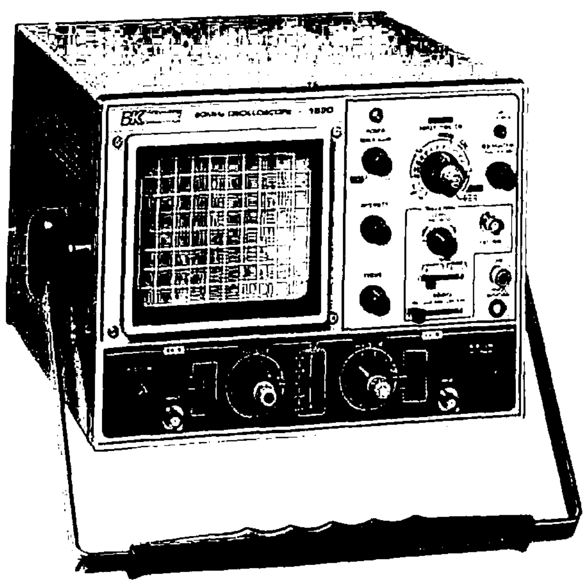
Just a decade ago high-frequency oscilloscopes were costly items that found extensive use only in commercial applications. Few Amateur Radio operators owned scopes at *all* — much less high-frequency ones. But that situation is changing. A number of manufacturers offer low-cost oscilloscopes that provide vertical bandwidths of 20, 50, or even 100 MHz. While not exactly in the "low-cost" category, these instruments are well within the range of many Amateurs.

This month I'll look at a method for placing either detected or raw RF on the input of an oscilloscope. I used an Amateur HF dummy load, a Drake DL-1000 (see **photo B**), as the basis for my measurement system. The modified internal circuit of the DL-1000 is shown in **fig. 1**. The main load is a 1000-watt, 50-ohm non-inductive resistor element mounted between the center pin of an SO-239 "UHF" coaxial connector (J1) and ground. The 1000-watt rating of the DL-1000 is based on a relatively short duty cycle, and that's appropriate for most Amateur Radio applications. If you need to run more power, or to operate into the load for more than a couple of minutes, Drake provides a cutout on the rear panel of the dummy load to accommodate a blower fan for forced air cooling.

I added two sampling elements to the internal circuitry of the DL-1000. I constructed both of 1/8-inch (3.18 mm) brass tubing. This tubing, available in hobby and model shops, is inexpensive and easily worked with a hacksaw or jeweler's saw. I terminated each sampling element in a 220-ohm, 1-watt resistor at the "cold" end. I connected the sampling element used to drive the RF sample port directly to the BNC jack (J3).

It's possible to use a wire loop, instead of the brass rods, for the sampling element. Build a 1-inch (2.54 cm) loop consisting of several turns of no. 14 solid insulated wire. Connect one end of the loop to the output jack (J2 or J3), and the other end to the resistor termination. (I've found that resis-

PHOTO A



Standard 5-inch dual-trace oscilloscope with 20-MHz bandwidth and triggered sweep. (Courtesy B&K Dynascan Corporation.)

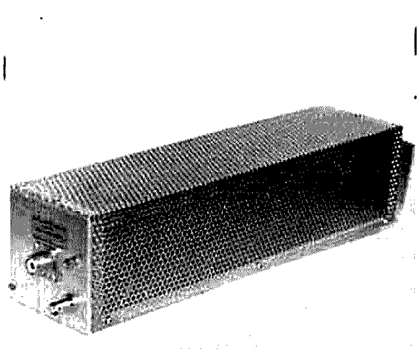
tor terminations aren't strictly necessary when using loops, so you might want to try connecting the loops between the output jack and ground first.)

You also connect the detected output (J2) to a brass rod sampling element, which is terminated in a 220-ohm resistance. However, there's a detector/rectifier network at the output end that demodulates the RF signal to produce a DC signal proportional to the RF power level. You can use this port for measuring RF power in CW (sinusoidal) waveforms, or looking at the waveform modulation on a low-frequency oscilloscope.

Photos C and **D** show the construction of the modified DL-1000. The internal structures appear in **photo C**, while the connectors at the output end are shown in **photo D**. The detected output connector is an RCA phono jack; the raw RF sample is a BNC jack. I used two different connectors; this makes it easier to tell them apart. But there's no reason why you can't use the same connector — either BNC (preferred) or RCA phono jack — for both. I wouldn't try an SO-239 UHF coaxial connector (used for the RF input to the load) for either the RF sample or detected outputs. It's possible that it could be mistaken for the main RF power input, with potentially disastrous results. A ground connector is also provided on the end plate. I haven't used it for anything yet, but it seemed like a good thing to have available.

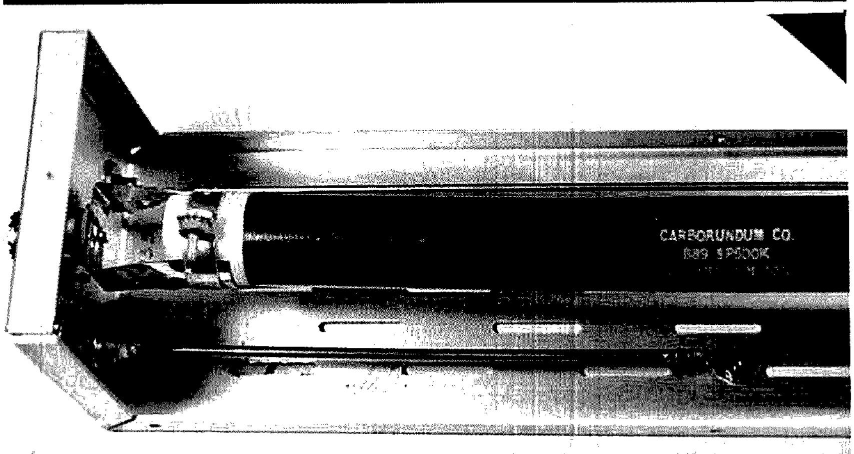
Photos E, F, and **G** show several outputs from the RF sampling jack. These waveforms were taken from the

PHOTO B



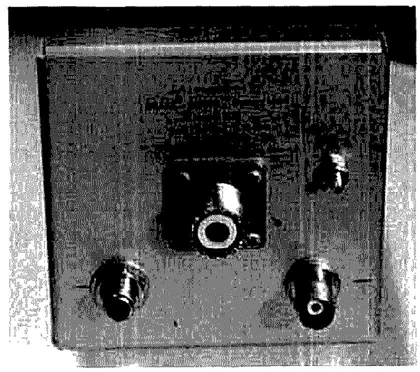
Drake DL-1000 dummy owned and modified by the author.

PHOTO C



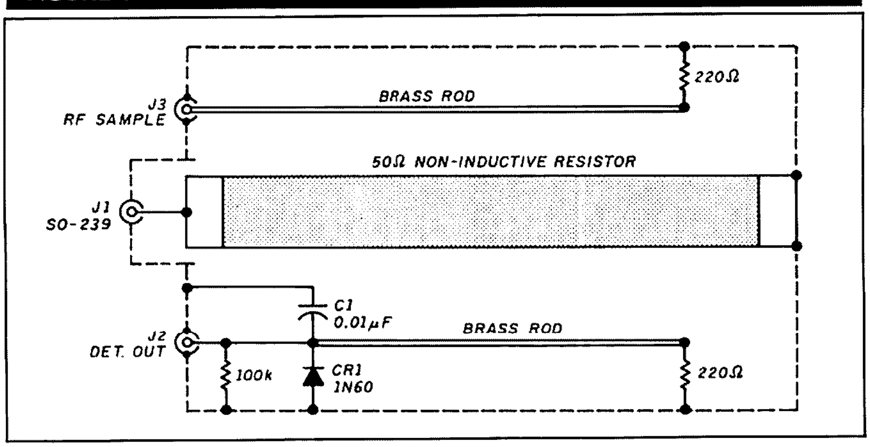
Construction of the sampling loop inside the DL-1000.

PHOTO D



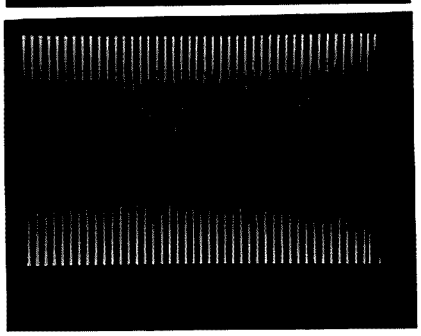
End panel showing the coaxial connector plus added RCA phono and BNC jacks.

FIGURE 1



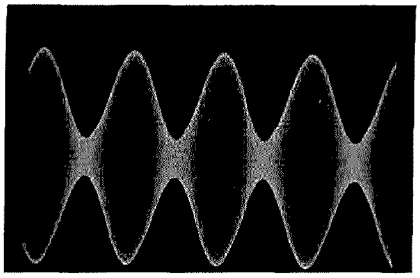
Schematic of the modified DL-1000.

PHOTO E



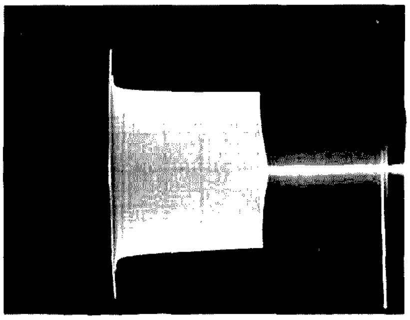
CW waveform.

PHOTO F



AM waveform.

PHOTO G



Keyed-CW waveform.

modified DL-1000 while it was excited by a 65-watt old-fashioned AM/CW HF transmitter. The oscilloscope has a 50-MHz vertical bandwidth. **Photo E** is a CW signal with key down. This signal was on the 75/80-meter band. Notice that the horizontal sweep is fast enough that individual cycles are resolved on the, screen. **Photo F** shows an amplitude modulated (AM) signal. The AM signal was single-tone modulated at 400 Hz, and the scope was adjusted to show several cycles at that frequency rather than the higher RF frequency. A keyed CW signal is shown in **photo G**. There are two methods for producing this signal. One is to turn on an electronic keyer and adjust the oscilloscope timebase to trigger on the repetition rate. Alternatively, you can use the scope's single-trace setting (if available) and take the photo at one shot.

Other uses for the brass rods

The preceding section discussed one application of brass stock in an electronics construction project. If you're into construction, especially RF projects, check out your local hobby shop. There are a lot of supplies, tools, and vision aids for those who do their building from the ground up. Of particular interest to electronic builders is the light metal brass stock. These are hollow rods, solid rods, square rods, rectangular rods, and flat plate sheets from strips of only 1/4 inch to sheets 4 inches wide.

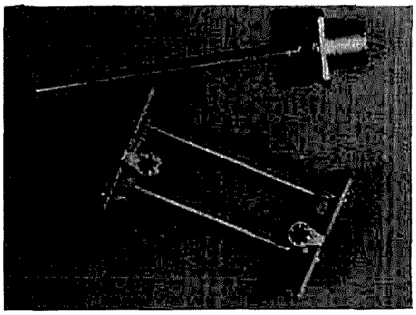
Photos H and **I** show an application for the hollow brass rods mentioned earlier. In fact, the small rods in **photos H** and **I** were cut from the same piece of stock as the rods used in the dummy load. The project is a monimatch type of VSWR coupler. It was intended for use inside an antenna tuning unit that I'm building.

A monimatch uses two short transmission line segments parallel to, and coupled with, the main transmission line segment. Pieces of ordinary perfboard support the transmission line segments at either end. One end of each coupler section is terminated in carbon composition resistors, while the other ends are terminated in 1N60 germanium diodes and 0.001-μF feedthrough bypass capacitors. There's nothing unusual about the design, except for the use of the brass rods as the transmission line and coupler segments.

I selected two sizes of brass stock. To determine the larger one, I took an SO-239 coaxial connector to the hobby shop and found a size that fit snugly over the solder connector of the center pin.

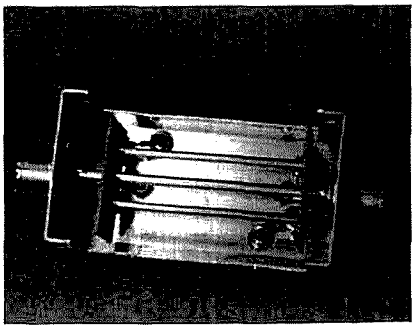
Sheet stock solders well, and can be worked easily with ordinary tools. I use scissors, lightweight sheet metal shears, and assorted other tools to work the brass. In one of my other lives I'm an amateur jewelry maker, and have found some interesting metalworking tools in jewelers' supply catalogues and local lapidary stores. Two of the best are the jeweler's saw and the parallel jaw pliers. The jeweler's saw is like a jigsaw with a very fine blade. (Buy a sleeve of spares — they break easily!) It lets you make very precise cuts and oddball shapes in metals. The parallel jaw pliers look like other pliers, but the jaws are designed to remain parallel to each other through the entire range of motion. This feature allows you to bend metal easily in straight lines, with straight edges. These pliers are especially nice when making shields for RF projects. On one project, I bent a 1-inch strip of brass stock at three points to form a rectangular shield around an RF receiver front-end circuit. I was then able to use a piece of wider sheeting for the shield cover.

PHOTO H



Disassembled view of the monimatch sensor.

PHOTO I



Assembled view of the monimatch sensor.

An RF shield is most effective when it's continuous. I know an electronics engineer with a lot of experience in microwave design. He once designed a transmitter and specified cabinet screws every 3/8 inch. But the wizened mechanical engineer who worked for the company felt he had used too many, and reduced the num-

ber to one every 4 inches. Hal ordered the new cabinet drilled and tapped according to original specifications. When the work was done, he set up a spectrum analyzer near the transmitter and called the mechanical engineer over for a little demonstration. With each screw he removed, the level of the signal on the spectrum analyzer rose higher and higher. Hal's point (aside from "don't mess with my designs") was that a lot of fasteners are needed to make the shielding effective. Of course, a continuous seam is even better.

You can fashion brass sheet stock into a box (or whatever shape you require) for shielding purposes. Instead of solder tacking the thing together, which will work mechanically, use a soldering gun or heavy iron to draw a solder bead along all seams. This makes it essentially RF proof. Doing this is a bit tricky, so be prepared to use alligator clips (or one of those "third hand" bench aids) to hold things steady while you work. If you shop for any of the tools I mentioned, pick up a spool of iron binding wire, too. Jewelers use this wire to bind things together while soldering. Solder tack the pieces of your project together using a small, 25-75 watt soldering pencil. Once the solder-tacked assembly is ready, use a heavier soldering gun (like the Weller D-440) to draw the bead around the edges. Be careful to fill in the gaps in the seam.

Conclusion

The Amateur Radio builder has a large array of electronic components and tools at his disposal. There are also many tools and supplies available from other hobbies and vocations — like the brass stock favored by model builders and the tools used by amateur jewelers. If you like electronic project construction, then go for it!

I can be reached at POB 1099, Falls Church, Virginia 22041; I'd like to have your comments and suggestions for this column.

Article C **HAM RADIO**

EASY MONITOR RECEIVER
FOR 2 METERS

Use weather radio as 2-meter monitor

By Courtney Hall, WA5SNZ, 7716 La Verdura Drive, Dallas, Texas 75248

Want to monitor the 2-meter band and part of the VHF-Hi band on the same receiver? Want to do it for less than $20? Read on.

I've found an inexpensive way to monitor 2 meters. Simply use a modified Radio Shack weather radio; all you need to do is add a jumper wire.

The receiver

I used Radio Shack weather radio catalog no. 12-181B; it's the one housed in a 3-inch cube. It normally sells for $17.95, but sometimes it's on sale for as low as $12.95. Radio Shack also sells some other crystal-controlled weather radios, but this modification won't work on them.

You get a lot of radio for your money in the 12-181B. It's a double-conversion superheterodyne with a fixed-tuned RF amplifier stage. The intermediate frequencies (IF) are 9.7 MHz* and 455 kHz. It's designed for use with narrowband FM signals only. Inside the IF integrated circuit (a Motorola MC3357) there's a five-stage limiter amplifier. This circuit clips off amplitude modulation when the 9.7-MHz IF signal is 5 μV or more. You won't hear any modulation from AM signals, even though their carriers will quiet the background noise. The 9-volt battery must deliver about 20 mA to the receiver during normal listening conditions.

This radio is designed to tune only the frequencies of the National Weather Service broadcast stations which operate on 162.40 through 162.55 MHz. In order to receive the 2-meter band, you must increase the tuning range to cover the frequencies from 163 MHz or higher down to 144 MHz or below.

*I don't know why the first IF is 9.7 MHz instead of the standard value of 10.7 MHz, but the Radio Shack service manual for the weather radio says it's 9.7 MHz.

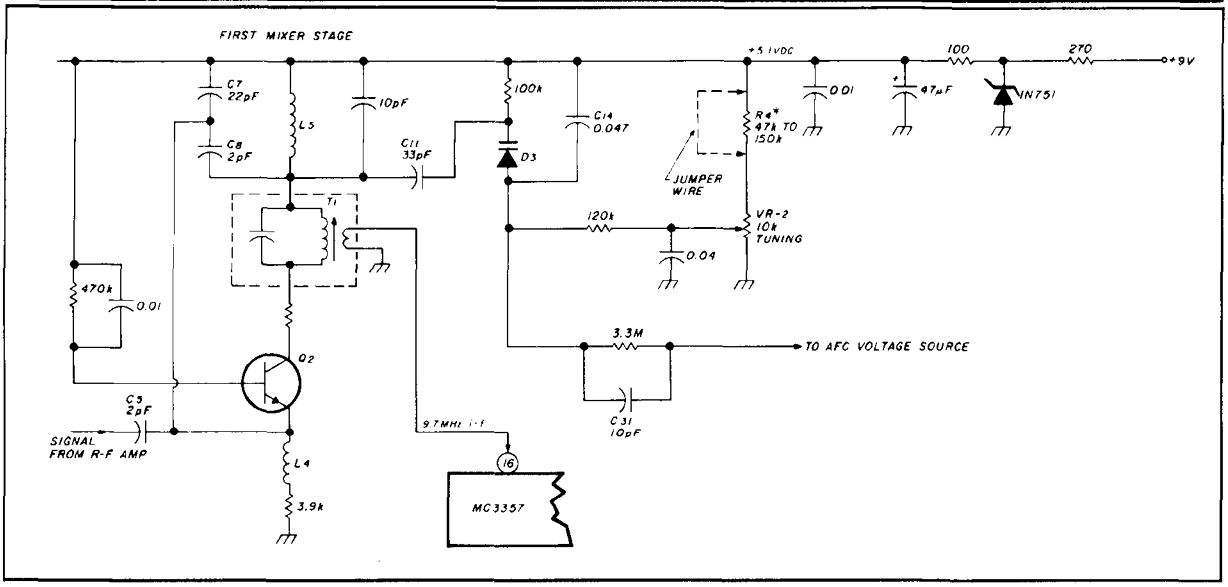
The modification

Receiver tuning is done with a 10-k potentiometer which varies the reverse-bias voltage across a voltage-variable capacitance diode. This diode, also called a tuning diode, is connected across the coil in the first local oscillator. The frequency produced by this oscillator mixes with the incoming signal frequency; the difference between the two frequencies is the first IF of 9.7 MHz. As the reverse-bias voltage across the diode increases, the diode's capacitance becomes smaller. Maximum diode capacitance occurs when the reverse-bias voltage is zero. To make the receiver tune to lower frequencies (down to 144 MHz or below) you must increase the capacitance across the oscillator coil. To do this, decrease the reverse-bias voltage applied to the tuning diode.

Figure 1 is a partial schematic diagram of the receiver circuit showing the first mixer stage, which incorporates the first local oscillator. L5 is the oscillator coil and D3 is the tuning diode. Adjusting VR-2 varies the reverse-bias voltage across D3; this tunes the receiver to different frequencies. R4 is a resistor whose value is selected at the factory to produce the desired tuning range for the weather broadcast frequencies. Connecting a jumper wire across R4 lets you reduce the reverse-bias voltage across the tuning diode to zero volts. This gives the tuning diode its maximum capacitance and tunes the local oscillator frequency low enough for 2-meter reception. The high-frequency end of the tuning range will be the same as it was before the modification.

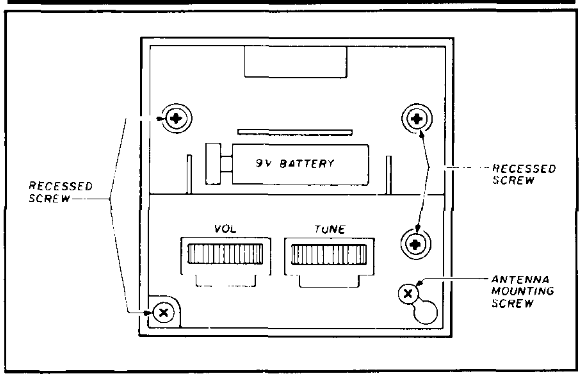
I found a few discrepancies between the schematic furnished with the radio and the actual circuit. Although Radio Shack's schematic shows a range of 47 to 150 k for R4, its value was 27 k in the unit I purchased. The

FIGURE 1



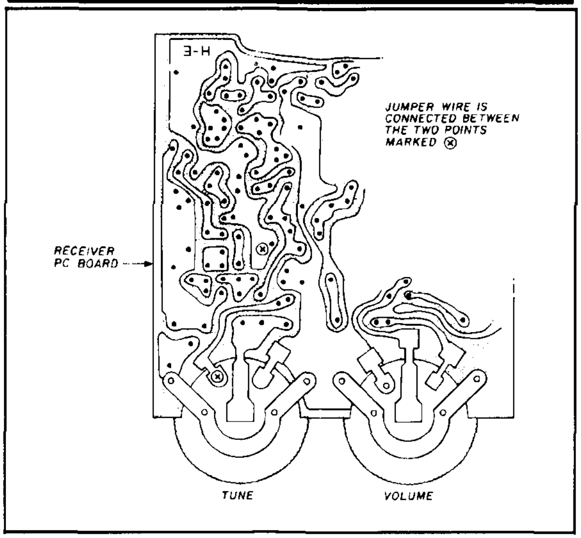
Partial schematic of Radio Shack Weather Radio, showing jumper modification needed for 2-meter hamband reception.

FIGURE 2



Bottom view of Weather Radio with cover removed.

FIGURE 3



Jumper wire is connected between the two points marked "X."

schematic also showed R4 connected to the + 9 volt line instead of to the + 5.1 volt point which is its actual connection.

How to do it

Turn off the radio by pressing the touch bar. Collapse the antenna to its shortest length. Remove the bottom cover by pressing the latch toward the center of the cover and lifting it out. Disconnect and remove the battery.

Next, loosen but do not remove the antenna mounting screw (see **fig.2** for the screw's location). Remove the four screws located in the deeply recessed holes of the case. Push the antenna mounting screw into the corner of the case, so that the head of the screw will pass through the large hole. Then separate the case from the receiver, while guiding the battery connector through the opening provided.

Cut a 1-inch length of hookup wire and remove 1/8-inch insulation from each end. Solder the wire to the circuit side of the printed circuit board as shown in **fig. 3.** Take care that solder points sticking up from the board

don't puncture the insulation of the hookup wire.

Put the radio back in its case, while guiding the battery connector and the antenna mounting screw through the appropriate holes. Replace the four screws which hold the case on. Position the antenna mounting screw into its slot and tighten. Connect the battery and place it in its nest. Reattach the bottom cover.

Now extend the antenna and turn on the radio. Tune in a weather broadcast and mark this point on the tuning knob with a dot of paint. This point should be near one end of the tuning range. You should find some 2-meter activity near the other end of the tuning range. When you do, mark the tuning knob with another color dot of paint.

That should do it. The fixed-tuned RF amplifier is still tuned to the 162-MHz weather frequencies, so sensitivity won't be optimum at the 2-meter frequencies. It is, however, adequate for casual monitoring. I believe any improvement gained by adding tuning controls to the RF stage wouldn't be enough to justify the effort. Good listening!

Article D **HAM RADIO**

MULTIBAND SPEECH PROCESSOR

Increase your station's output power at minimal cost

By Robert Wilson, KL7ISA, Box 34298, Bethesda, Maryland 20817

An audio processor is a circuit between the microphone and the radio frequency modulator in a transmitter's audio system. A properly designed processor gives a real boost to your transmitter.[1] A 1.5-kW PEP Amateur station can run an effective 12 kW to its antenna with the addition of a multiband speech processor.

I've designed a simple SSB speech processor built with parts from the local radio store. This processor will give your signal about a 6 to 9-dB increase in signal readability or "punch" in the presence of noise or interference.

Communications speech processors should make the spoken word more intelligible in the presence of noise. These processors don't necessarily need to retain a natural sound, as would a processor designed for broadcast use. According to John Birch, W3JB, Chief of Audio Engineering for the Voice of America, there's a big difference between the various types of processors. Their design is based on the kind of sound a station desires and the particular function it requires.

I found that processing is more efficient if you break the voice down into several different voice bands. This lets you optimize, clip, and adjust each band separately for the required level. Then the signals are added together and clipped once more. The output gain is equalized to the unprocessed microphone level, and the processed audio is sent to the transmitter.

It's easy to build a speech processor like mine. The schematic is shown in **fig. 1**; it's constructed using a "perfboard" layout. I bought all my parts at the local Radio Shack, but sometimes had to series resistors together to get the correct values. I used high quality 0.01-μF film capacitors to determine frequency. I kept all leads as short as possible to avoid RF pickup, and shielded the input and output audio leads for the same reason. My circuit incorporates the well-known "tack together and solder blob" style. A real printed circuit board would speed things up a lot and assure that there are no errors.

Upon completion, I checked the circuit to make sure there were no shorts and that it followed exactly the schematic I had drawn. As a finishing touch, I mounted the speech processor in a metal project box with silicone glue, checking for unwanted grounds to the box.

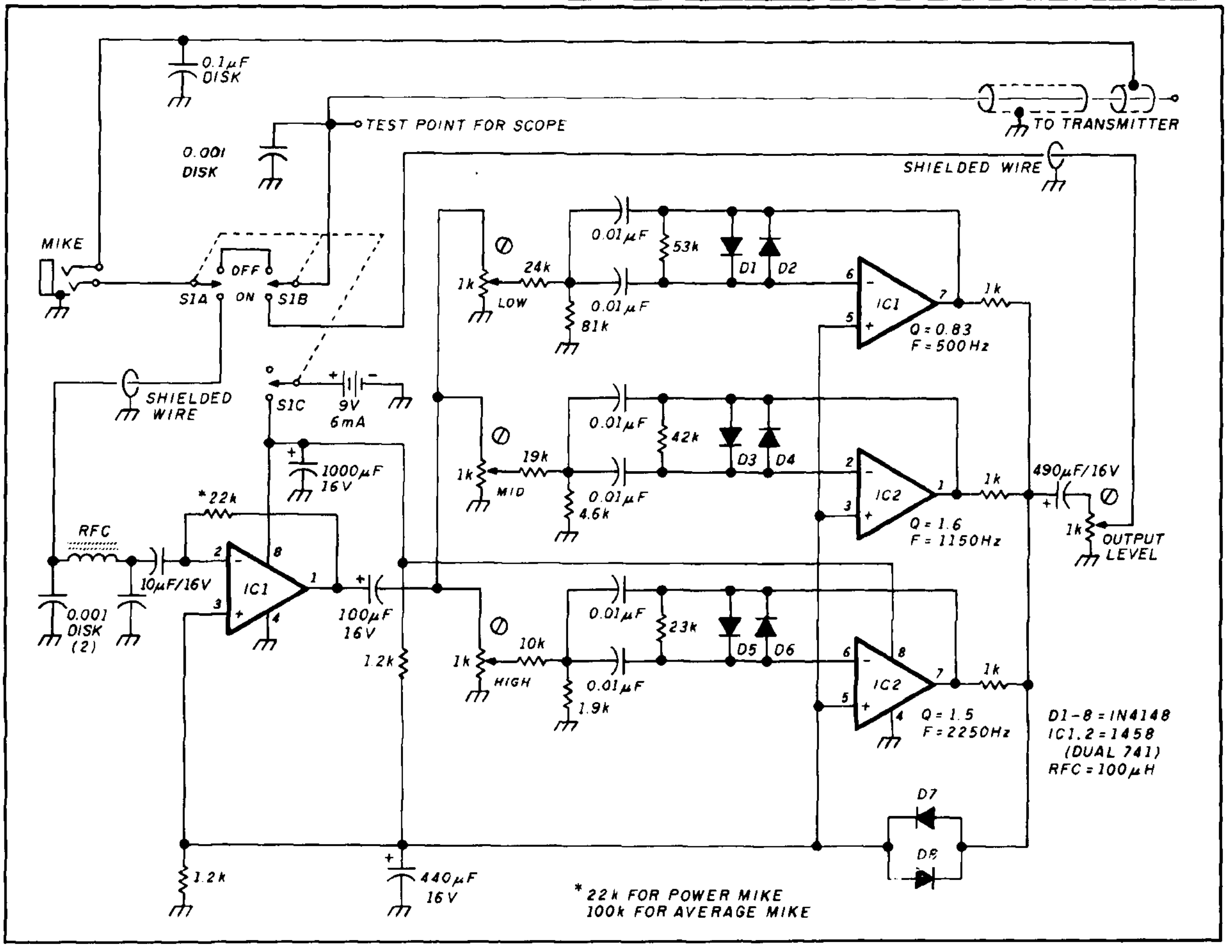
This speech processor is almost foolproof. It's possible to turn all four pots to maximum, plug in any low-impedance mike, and obtain fair results. For best results, get a noise-canceling power microphone (Radio Shack has them) and plan to dedicate it to this processor. The noise-canceling mike prevents background noise from increasing and blanking out the desired weak voice signal sounds. For best operation, tune the processor for your own voice, microphone, transmitter, and same general size of speaker where you expect your signals to be received. After your final tuning, lock the controls and forget them. They are personalized and shouldn't need to be touched again.

I found that the Radio Shack amplified microphone required special RFI suppression to operate in my high-powered mobile station. I opened the case and placed a very small 0.001-μF ceramic disk capacitor between terminals 9 and 10 on the pc board. (This capacitor must clear the side of the case or it will be impossible to reclose the microphone properly.)

The tune-up procedure requires rotating all four controls to maximum. Plug the processor output into your mike jack and your transmitter into a dummy load, or use a dead band for tune-up. Set the modulation control on the transmitter for normal output level on voice peaks. Now with the help of a friend or a second receiver, tune in your own signal. If possible, try a speaker the same size you'd expect most DX operators to use.

Try adjusting the low-frequency band control first, using a standard test sentence like "the quick brown fox jumped..." This band contains most of the power audio frequencies, but it's not the band that contains most of the intelligence. Be very critical of what you

FIGURE 1



Schematic diagram of the multiband speech processor.

hear. Use the criterion, "Can I understand this signal better in the presence of noise?" not "This signal sounds more natural!" Adjust the high-band control using the same criterion. Finally, adjust the mid-band control if necessary. You'll probably need two or three adjustment sessions before final control lockdown.

When you're through tuning the three band level controls, your voice may sound a bit harsh, but not particularly strident. If you have an oscilloscope, you can turn the processor off and measure the microphone audio peaks. Look only for the peaks — the processor will change the audio density greatly. The change shows up clearly on the scope. Now you can compare the results of processed audio with the unprocessed audio simply by switching between the two. The results should be remarkable even to an untrained ear.

At 1 kW my mobile station is considerably larger than most, but I still need lots of effective power to compete with fixed stations running 1.5-kW PEP and using beam antennas. That's why I added the multiband speech processor in line with the microphone. I set the transmitter modulation control to run full power with the processor turned on. Power peaks in this situation are about the same with the processor on or off. When I switch it off, my signals are unusable in the presence of noise or QRM — but with the processor on I can compete with the crowd. I believe it adds a good 6 to 9 dB to the effective power of my station under these conditions. This boost is the equivalent of 8 kW or 3 S-units. It certainly makes a difficult transmitting situation easier and helps me work mobile DX.

Reference

1. W.W. Smith, W6BCX, "Premodulation Speech Clipping and Filtering," *QST*, February 1946.

Article E

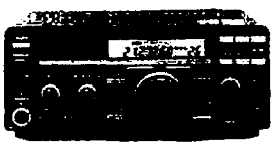
HAM RADIO

NEW products

Ultra-compact IC-725 HF transceiver

ICOM has introduced the compact IC-725 HF transceiver. The all-mode IC-725 features:

- USB/LSB/CW transmitting and receiving, AM receiving, optional module no. UI-7 for FM transmit/receive, and AM transmit.
- Twenty-six tunable memories with band stacking registers.
- DDS (Direct Digital Synthesizer) system
- Built in AH-3 controller. (Optional AH-3 automatic antenna tuner available.)
- Three scanning systems: programmable, memory, and selected mode
- Priority watch
- 105-dB dynamic range receiver
- 160 through 10-meter operation. Short-wave reception from 30 kHz to 33 MHz.



Other features include: panel-selectable RF preamp and attenuator, dual VFOs, noise blanker, RIT, semi-break in CW, selectable AGC, a full-duty cycle, and optional narrow CW filter.

The suggested retail price of the IC-725 is $949. For more information contact ICOM America, Inc., 2380 116th Ave., NE, PO Box C-90029, Bellevue, Washington 98009-9029.

Circle #301 on Reader Service Card.

High power, special purpose baluns

RADIO WORKS has three new types of baluns. The B1-2K and B1-4K Utility baluns are low-loss, wideband, 1:1, "current-type" 50-ohm baluns with large, saturation-resistant ferrite cores. Controlled winding reactance gives a nearly flat VSWR curve from 160 to 10 meters. Power rating is 1500 watts for the B1-2K and 4 kW for the B1-4K. All connections are soldered and leads from the internal transmission line brought outside the case for direct connection to the antenna wire. Each balun is completely potted. They are designed for use in wire antenna systems. The price is $15.95 for the B1-2K and $19.95 for the B1-4K.

The RemoteBalun© mounts outside where it connects to a balanced transmission line. A short length of low-loss coaxial cable connects the balun to a Transmatch.

Power rating is 1.5 kW in low-duty cycle CW and SSB applications; the price is $27. Optional interconnect coaxial cables with connectors are available.

The C-series (Stick Balun©) line is for retrofit applications in existing wire antennas and beams. The C1-2K enhances antenna operation by improving transmission line isolation and balance. The Stick Balun is a low-loss design with high transmission line isolation. Winding reactance is 1100 ohms at 3.5 MHz. Power rating is 1.5 kW and the core saturation resistance is high. Phase delay is 2.6 degrees at 3.5 MHz. There are 75-ohm models available for use with the quarter-wave matching sections. The price for the C1-2K and C75-2K is $15.95. Higher power models are available.

For more information or a catalog, write the RADIO WORKS at Box 6159, Portsmouth, Virginia 23703.

Circle #302 on Reader Service Card.

Voltage surge protection

American Voltage Products surge protection devices provide the home and commercial user with equipment protection at optimum dollar value.

The VSS-1 is for use on any 120-Vac single or three-phase distribution panels and clamps at 160 Vac while providing 70,000 watts and three-leg protection. The unit comes with 18-inch leads and protects computers, VCRs, stereos, typewriters, FAX machines, TVs, telephone systems, process controllers, motors, microwave ovens, home video games, appliances, and more.

The VSS-7 coaxial power cube (standard 1.4"×1.2"×8") has male and female coax connectors. The unit is rated to clamp at 160 Vac with a 70,000-watts rating, 6,500 A maximum. The cube is designed for use with 75-ohm cable and is applied in data links in building coax networks or the antenna side of cable television.

For more information contact American Voltage Products, Inc., 18 Morse Drive, Essex Junction, Vermont 05452.

Circle #303 on Reader Service Card.

Full remote frequency control with FC-900 Interface

Advanced Computer Controls, Inc. announces the new FC-900 Interface, supported by several of its repealer controllers. The FC-900 Interface permits use of the ICOM IC-900 transceiver band units as remote base and link transceivers. The system approach is cost effective as only the band units are needed, not the ICOM fiber optic controller and interfaces. Hookup is simple.

Full remote frequency control is available through Touch-Tone commands. Amateur frequencies are supported on six bands from 29 to 1300 MHz.

Remote bases and links let you extend the range of the repeater, link it to other repeaters for emergency and public service use, and benefit from the site elevation on all bands.

The price of the FC-900 Interface is $225. An optional programmable CTCSS encoder is $25. For more information contact Advanced Computer Controls, Inc., 2356 Walsh Avenue, Santa Clara, California 95051.

Circle #304 on Reader Service Card.

Two new repeater modules

Hamtronics, Inc. has announced two new products for building VHF and UHF repeaters.

The COR-4 COR/CWID module is a new low-power unit which combines all the features of the CWID and COR-3 (including courtesy beep) in one 3"×7" module. This new unit uses CMOS logic and an EPROM for programming. Introductory price is $99 for the kit or $159 wired and tested.

The TD-3 Subaudible Tone Decoder/Encoder can be used with any subaudible tone on Hamtronics or most other receivers. It has repeater service features (like remote on/off capability when used with TD2 Touch-tone module). The price is $24 for the kit, $69 wired and tested.

For a catalog on the entire line of repeater modules send $1 to Hamtronics, Inc., 65-F Moul Road, Hilton, New York 14468-9535.

ANALOG PANEL METERS

Take advantage of analog panel meter benefits

By Hugh Wells, W6WTU, 1411 18th Street, Manhattan Beach, California 90266

Even though most electronic devices are digital these days, analog meters are still popular. You can find them at garage sales, swap meets, surplus outlets, and in many Amateurs' junkboxes. There's a good, reasonably priced selection to choose from. Panel meters were designed as single-application indicators, but you can easily convert them to other uses with external circuitry.

Because some meters have unusual markings, many shoppers bypass valuable ones at swap meets in lieu of those that look more familiar. A meter's value lies in its sensitivity and its ability to adapt to a new use, regardless of its original scale markings. If you're careful, you can change scale markings on non-hermetically sealed meters and increase the instrument's versatility.

The more you understand about a specific instrument, the easier it is to use. My computer program* helps me develop external circuit values to meet new applications for my panel meters, using the techniques that follow.

Theory

Meters are used to measure voltage, current, resistance, power, RPM, temperature, and other electrical and electro-mechanical functions. Each converts a function to an electrical signal, and then to a pointer position on the meter scale. There are many types of meters that provide indications of an electrical quantity. Analog panel meters are current operated (versus electrostatic). Current-operated meters work as a result of electromagnetic motor action, where the mechanical movement of a pointer is proportional to a magnetic force. The force develops between a permanent magnet and the magnetic field created around a coil of wire through which a current flows.

Two of today's popular meter movements use electromagnetic motor action: the plunger (moving iron) and the D'Arsonval type. The D'Arsonval uses a moving coil, and is preferred because of its indication sensitivity and repeatability. The plunger-type meter is more suitable for applications where the accuracy of an indication is unimportant.

The D'Arsonval meter uses a horseshoe magnet with its open ends close together, creating a magnetic gap. Soft iron pole pieces with semicircular ends are fitted to the ends of the magnet to narrow the gap, and create a uniform magnetic-field pattern that translates to a linear-scale indication. The semicircular ends face each other, forming a round gap area. Some meter manufacturers cut the pole pieces on a bias. This creates a nonlinear function which satisfies a particular application. The majority of pole pieces are cut straight to provide linear indications. A round piece of soft iron is mounted

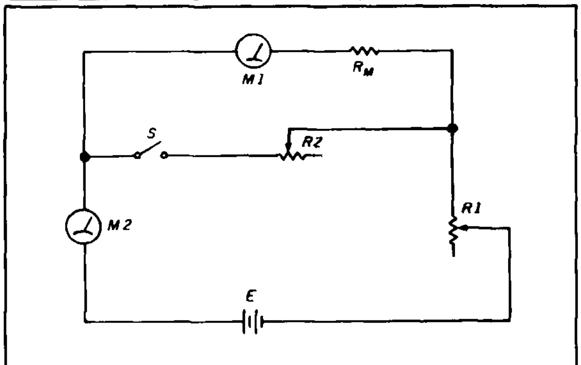
*Send a large self-addressed stamped envelope to *Ham Radio* Magazine, Greenville, New Hampshire 03048. Ask for W6WTU computer program. Ed.

between the semicircular pole pieces, concentrating the field pattern within the gap.

A moving coil, made of many turns of small diameter wire wound into a rectangular shape, is mounted lengthwise around the center pole piece. Some coils are wound onto an aluminum frame/bobbin; others have no bobbin. In either case, the coil must be lightweight, with a shape that lets it move freely in the gap between magnet and center pole.

Pointed-wire pins called pivots are mounted (usually cemented) to the coil in the axis of rotation, along with spiral springs and an aluminum pointer. The pivots provide a low-friction bearing surface for the coil. In some meters the coil is mounted with a taut band instead of pivots. The taut band reduces the bearing-surface friction and improves indication accuracy and repeatability. A twist in the taut band creates the return spring function provided by the spiral springs used with pivots. The complete coil assembly is called a meter movement.

FIGURE 1



Technique for measuring internal resistance.

Internal resistance

Wound wire makes up the coil portion of the movement. The wire has a resistance depending on wire diameter and length. The completed coil has an internal resistance (R_m), which you need to consider during all external circuit calculations. There are some applications (like voltmeters) where R_m is small compared to the multiplier resistance and can be disregarded. Meter applications involving a shunt (an ammeter, for instance) require that R_m be considered in the external resistance calculation.

Generally the value of R_m is unknown, but you can determine it using an indirect measurement method. Attempting to measure R_m by direct means (as with an ohmmeter) could cause excessive current or voltage to be applied to the meter coil and damage it. An indirect measurement method is shown in **fig. 1**. This method involves adjusting R_1 for a full-scale deflection of M_1 with a voltage source (E). Resistor R_2 is then attached in parallel with M_1 and decreased in value until M_1 indicates exactly one-half the full-scale value.

TABLE 1

Typical internal-resistance values as a function of coil current.

I_m	R_m (ohms)
15-20 μA	4000
50 μA	1200
100 μA	850
200 μA	600
500 μA	150
1 mA	76
2 mA	60
5-10 mA	16

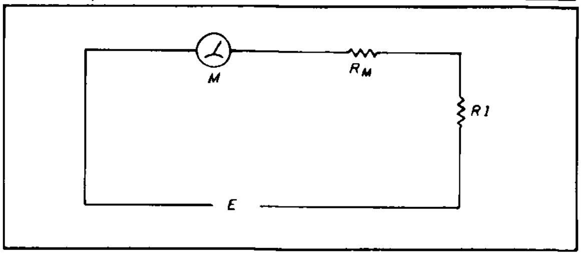
You may need to adjust R_1 slightly to maintain the same total current indicated by M_1 while at full scale. Meter M_2 is an indicator ensuring that total current remains constant as you adjust R_1 and R_2. In theory, the resistance of R_2 is exactly equal to R_m, and the combined current of R_2 and M_1 is equal to the original M_1 full-scale current. You can measure the resistance of R_2 with an ohmmeter for the value of R_m, after disconnecting it from M_1. The indirect method yields a reasonably accurate value of R_m, suitable for external circuit calculations.

Table 1 shows a listing of R_m values developed emperically from meters of different current ranges and manufacturers. You may use the table values to estimate R_m as a function of current. However, there's no specific value of R_m suitable for all meters of a specific current range. The actual R_m value varies by manufacturer, full-scale current value, strength of the magnet, gap spacing, and the number of turns and diameter of wire on the coil. Identifying an R_m value to within 20 percent of actual is usually sufficient for most Amateur applications, but a closer value may improve calibration accuracy. You can correct the meter calibration error introduced by an estimate of R_m when selecting your external resistors.

Accuracy

An instrument's measurement accuracy depends on many factors. These are functions of manufacturing tolerances and external circuitry. The typical accuracy of a D'Arsonval panel meter is 2 percent. That tolerance degrades to 3 to 5 percent with the addition of external multiplier resistors and rectifiers. Meter accuracy is normally determined at the full-scale value, and the resulting error is applied to all remaining scale indications. Some measurement applications require an accurate single-point indication. A 2-percent full-scale instrument with low-pivot friction and repeatable pointer positioning can yield a single-point calibration accuracy of 0.5

FIGURE 2



Single-range DC voltmeter.

percent or better. But, you should consider other points on the same scale as having an accuracy depending on the full-scale tolerance value — not equivalent to the single-point calibration accuracy.

Sensitivity

You can define meter sensitivity by either full-scale current or ohms-per-volt value. Meter sensitivity is most commonly defined in ohms-per-volt. It's determined by the amount of resistance that must be used in series with the meter to cause a full-scale deflection when 1 volt is applied. For instance, a 1-mA meter has a sensitivity of 1000 ohms per volt, and a 50-μA meter has 20,000 ohms per volt. Disregard the internal resistance (R_m) value when determining sensitivity.

Applications

Whether you can use a meter directly depends on its application and the external circuit in which it's placed. Few panel meters are used without external circuitry. Resistors are added externally for DC applications; resistors and rectifiers are added for AC use. You may use a bridge rectifier in a metering circuit to satisfy a nonpolarized DC application. The changes in scale factor result from the addition of the rectifier.

DC voltmeter

To use a panel meter as a voltmeter (see **fig. 2**), you'll need a series-connected resistor (R_1) to reduce the current to the desired amount. Determine the value of R_1 by:

$$R_1 = \frac{E}{I_m} - R_m \qquad \textbf{(1)}$$

where
R_1 = multiplier resistor value
R_m = internal resistance of M
I_m = full-scale meter current
E = desired full-scale voltage value

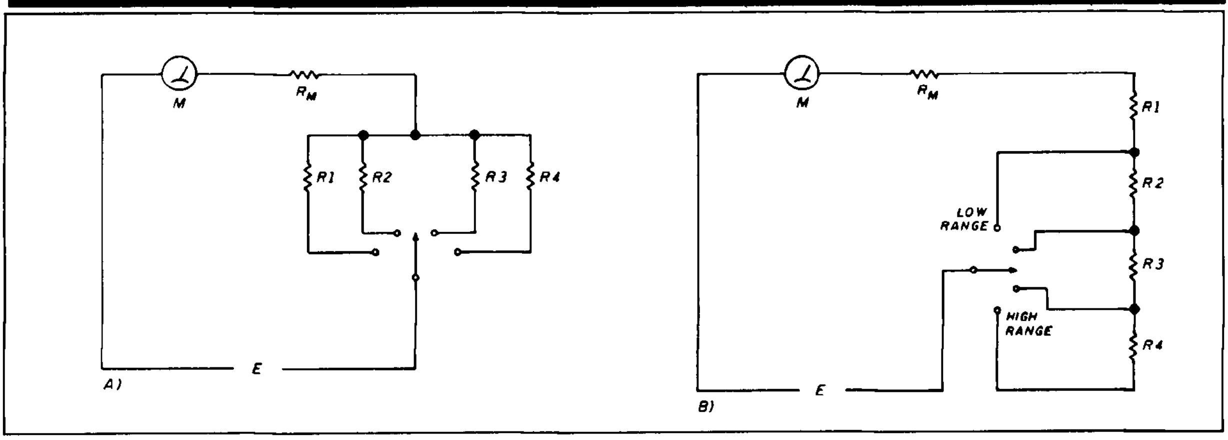
A single multiplier resistor satisfies the need to measure voltages less than the full-scale value. Switching additional resistors into the circuit for R_1 lets the meter function over different voltage ranges. I've shown two multiple-range circuit techniques. **Figure 3A** shows a switch used to select an independent value of R_1 for each desired range; **fig. 3B** shows stacked incremental resistor values. Determine the value of each resistor by using **eqn. 1** for **fig. 2**. Now you can determine the value of each resistor sequentially, after calculating R_1. (R_m is usually disregarded.) Define each additional range resistor by calculating the total resistance value, then subtracting from it the sum of the previously determined values (see **eqn. 2**).

$$R_x = \frac{E_{Range}}{I_m} - (R_m + R_1 \cdots R_4) \qquad \textbf{(2)}$$

where
R_x = total multiplier resistance value
E_{Range} = desired full-scale range voltage
I_m = full-scale meter current
R_m = internal resistance
$R_{1\text{-}4}$ = incremental-range resistance value

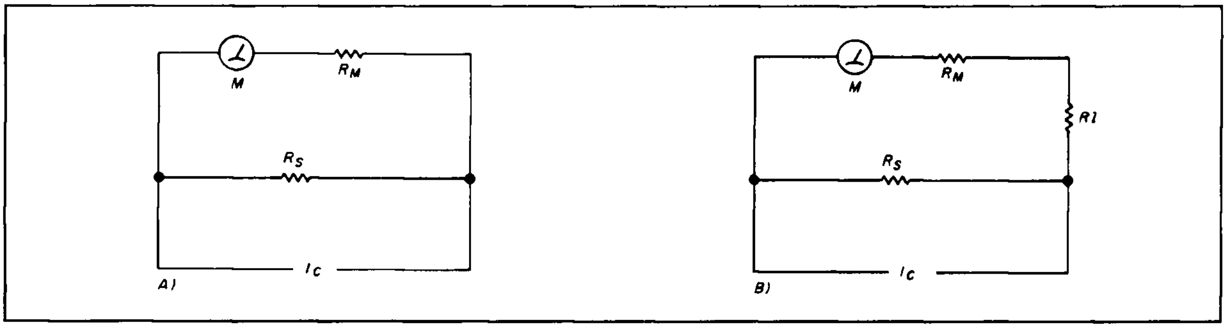
You can consider tradeoffs when selecting one rang-

FIGURE 3



Multiranging voltmeter. (A) Individual resistor multiplier. (B) Stacked resistor multiplier.

FIGURE 4



Ammeter circuits. (A) Shunt multiplier. (B) Series and shunt multiplier.

ing method over the other. Scale accuracy for the circuit in **fig. 3A** depends on each individual series resistor. For **fig. 3B**, the scale accuracy depends on the resistor tolerance of each lower range value in the stack. Perhaps the main advantage of **fig. 3B** over **fig. 3A** occurs when the meter is used to measure high voltage. If you use carbon resistors, you must consider — and not exceed — the voltage breakdown of each. Typical carbon resistors have a maximum safe voltage drop depending on their physical size. This may be translated to wattage: 1/4 watt = 100 volts, 1/2 watt = 300 volts, 1 watt = 500 volts.

Ammeter

An ammeter differs from a voltmeter in that it's connected in series with the external circuit, rather than in parallel. The ammeter is placed in series with a voltage source and its load circuit; this allows the meter to indicate the current drawn by the load. A shunt is placed in parallel with the meter coil, so only a portion of the external current flows through the coil. The amount that flows through the meter is a linear indication of the total current. The remaining current flows through a shunt resistor as shown in **fig. 4A**.

When you calculate the shunt value, you must know the full-scale current value, internal resistance, and the shunt current. Determine the shunt resistance by

$$I_{Rs} = I_c - I_m$$

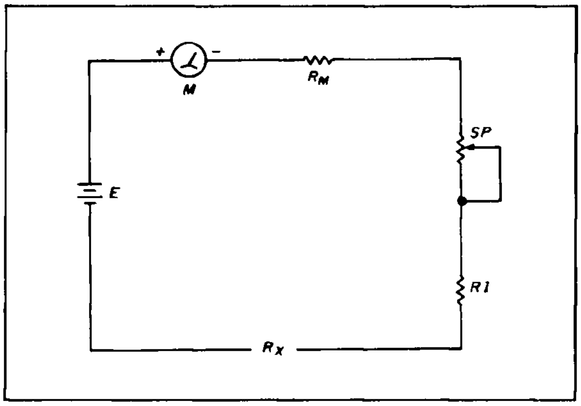
$$R_s = \frac{R_m \times I_m}{I_{Rs}} \tag{3}$$

where
R_s = shunt resistance
R_m = internal resistance of M
I_m = full-scale meter current
I_{rs} = shunt current
I_c = external circuit current

As the circuit current to be measured becomes very large (as compared with the meter-coil current), the resistance of the shunt becomes very small — sometimes too small to be easily managed. Solve this problem by adding a resistor in series with the meter. This allows it to function as a voltmeter. It will then measure the voltage drop across the shunt, as shown in **fig. 4B**. Although the meter is measuring voltage, its scale is calibrated in current. Assume that a current of 10 A is flowing through an R_s value of 1 ohm. E = 10 volts by Ohm's Law, and you'd select a value of R_1 which would provide a full-scale indication of 10 volts (10 A) on the meter.

Multi-ranging an ammeter requires a current-scale switching method theoretically involved in selecting a value of the shunt resistor for each current range. However, it's better to perform the range switching in the low-current circuits where switch-contact resistance has the least effect on the resulting indication. With R_s as a single fixed resistor, you may select values of R_1 to provide a multi-range capability.

FIGURE 5



X1-series ohmmeter.

Ohmmeter

An ohmmeter indicates the resistance of an unknown circuit or circuit element. Because it is a resistance detector, the ohmmeter can also be used to check circuit con-

tinuity. Sometimes knowing if the circuit is continuous is more important than knowing its resistance value.

The ohmmeter is essentially a voltmeter with an internal, rather than external, voltage source (see the series type in **fig. 5**). The pot (SP) and resistor R_1 make up the multiplier resistor allowing the voltage source to drive the meter to full scale. A fine-current adjustment, made with the pot, lets you obtain a full-scale indication when R_x (**eqn. 2**) is equal to zero. The scale calibration on a series ohmmeter is the reverse of that on a voltmeter scale. The $R_x = 0$ point is at full scale, with discernible measurement values read more easily in the upper three-fourths of the scale. (The scale values are usually too compressed in the lower quarter of the scale and provide only an approximation.)

Placing an unknown resistor (R_x) in series with the ohmmeter circuit causes a decrease in total current. The new lower current value is then translated to a resistance value for R_x on the meter scale.

When selecting circuit-component values and calibrating the ohmmeter scale, make several assumptions for the sake of convenience. After you've determined the total multiplier-resistance value for the circuit, assume that the working portion of the pot value is 10 percent of the total. To allow for pot adjustments, select the pot's total resistance to be 15 percent of the total circuit resistance.

Develop scale values for an ohmmeter through an iterative process by decreasing the meter current in increments and calculating R_x at each increment. The equation for determining a value of R_x is

$$R_x = R_t \frac{I_1 - I_2}{I_2} \qquad \textbf{(4)}$$

where

R_x = unknown resistance value

R_t = total circuit resistance (when $R_x = 0$)

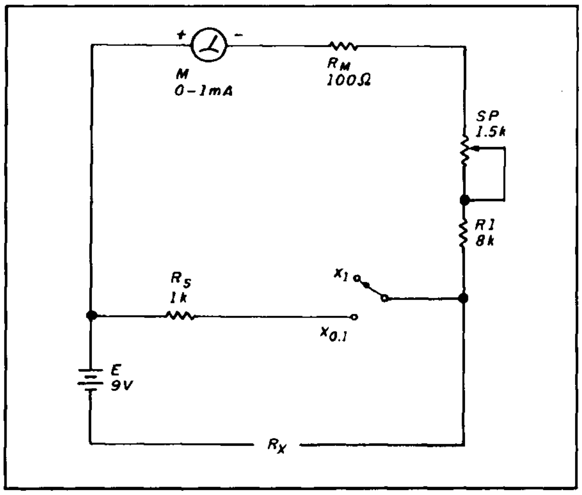
I_1 = full-scale circuit current

I_2 = circuit current value when $R_x > 0$

You can establish a multi-ranging capability for an ohmmeter by selecting the source voltage and full-scale meter current for the desired resistance range. Choosing a high-voltage source and a low meter current will provide a high-resistance measurement range. Likewise, increasing the circuit current through R_x will lower the measurable range. Many circuit designs have been developed for multi-ranging an ohmmeter. I'll discuss three examples.

Example 1. You can make a very low range ohmmeter by modifying the circuit of **fig. 5**. The unknown is in parallel with the meter coil, instead of in series with it. If the meter R_m is 100 ohms, the measurable range of R_x is from zero to about 500 ohms with 100 ohms at midscale. Placing a shunt across the meter and raising circuit current further reduces the R_x range to perhaps 0 to 50 ohms with 25 ohms at midscale. Placing R_x in parallel with the meter coil causes the ohmmeter scale to indicate that R_x is equal to infinity at full scale, instead of the normal zero at full scale for a series type.

FIGURE 6



Dual-range ohmmeter.

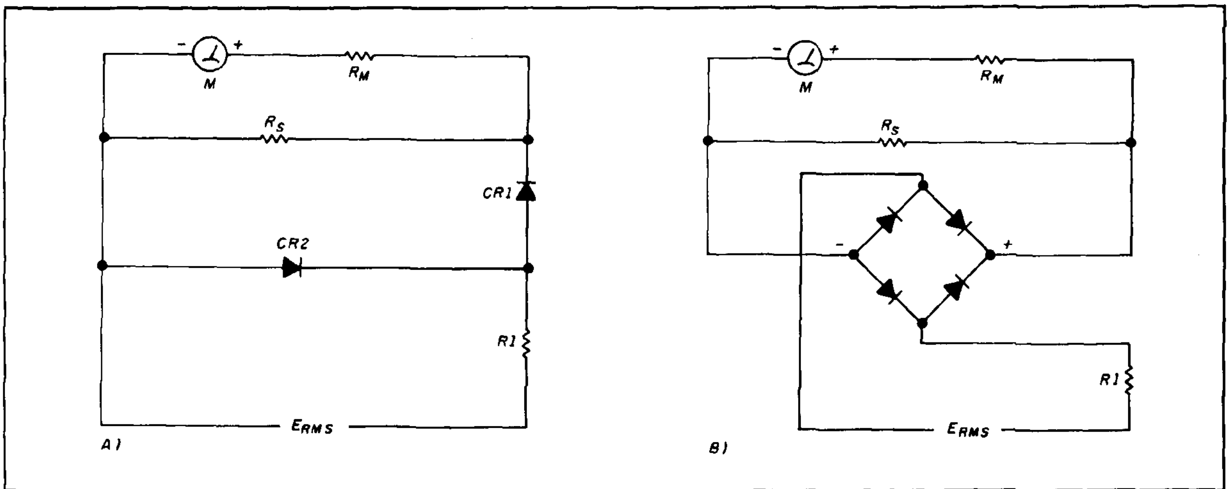
Example 2. By adding a high-voltage source and compensating R_1 value to the circuit shown in **fig. 5**, you can extend the measurable R_x range to several megohms.

Example 3. In **fig. 6** a typical series ohmmeter circuit has a shunt in parallel with the meter to raise the external circuit current. You can switch the shunt in and out to provide an X_1 and $X_{0.1}$ range capability. In this example, I've provided circuit values for analyzing the currents involved. With the shunt in place, the external current will have been raised over the meter current by a factor of 10. At $R_x = 0$, 10 mA will flow through the external circuit and 1 mA will flow through the meter, providing a current ratio of 10:1. The value of current difference between the meter and the external circuit will flow through the shunt (i.e., 9 mA). The resulting resistance-measuring range will be from 0 to 5000 ohms with 450 ohms at midscale. With the shunt removed, the measurable range will be 0 to 50,000 ohms with 4500 ohms at midscale.

AC voltmeter

You can also use a DC panel meter to measure AC voltages by adding a rectifier to the metering circuit. Measurement values will be different from those with DC because of the rectifier, and because the meter movement will respond only to the average current. Assuming a sine waveform and a half-wave rectifier, the current flow through the meter coil will be about 63 percent of the peak value for one-half cycle. On the other half cycle, the current will be zero. The meter movement will average the two values, producing a pointer position

FIGURE 7



AC-voltmeter circuits. (A) Half wave. (B) Bridge.

equivalent to 45 percent of the root-mean-square (equivalent DC) input. The scale would be calibrated in rms.

When you use a bridge rectifier, both half cycles will cause coil current to flow, allowing the pointer position to move to the equivalent of 90 percent of the rms input. This is twice that of a half-wave rectifier. Again, the scale would be calibrated in rms.

Calculate the series multiplier resistance used with either rectifier using the following equations.

Half-wave rectifier:

$$R_1 = \frac{0.45 \times E_{rms}}{I_m} - R_m \qquad (5)$$

Bridge rectifier:

$$R_1 = \frac{0.9 \times E_{rms}}{I_m} - R_m \qquad (6)$$

where

R_1 = multiplier resistor value

E_{rms} = full-scale rms voltage value

I_m = full-scale meter current

R_m = internal resistance of M

The actual multiplier resistance value must be reduced by the series-forward resistance value of the rectifiers, or by an alternative method of subtracting the forward rectifier drop from E_{rms} for the calculation.

Figure 7 shows half-wave and bridge rectifier circuits commonly used with DC meters for making AC voltage measurements. You use two diodes in the half-wave application, with CR_1 allowing current to flow through the meter. Diode CR_2 conducts on the alternate half cycle, preventing the voltage across the meter rectifier from rising to the source voltage. A high-reverse diode voltage could cause a sufficient leakage current to flow, resulting in meter indication errors. The two diodes, each conducting on alternate half cycles, keep the reverse voltage drop across the other diode to a small value. This means the reverse breakdown voltage of the diodes can be much less than the voltage being measured. Typically, the diode peak reverse voltage (PRV) is in the range of 25 to 100 volts.

Diodes have a square law forward-conduction curve which, if allowed, would cause the meter's scale values to be nonlinear, particularly at low points on the meter scale. In an attempt to maintain measurement scale linearity, diode conduction currents are kept fairly high, placing the operating point on the vertical (nearly linear) portion of the diode's forward-conduction curve. Increase the diode current by shunting the meter, thereby lowering the sensitivity value. An AC voltmeter will have a sensitivity of 5 or 10 k per volt. However, if the basic meter sensitivity is less than 5 k, additional meter shunting is seldom necessary.

Computer program

The computer program mentioned earlier was written on an Atari in BASIC. I developed it around the circuits I've described to ease the implementation of panel meters for new applications. I've tried to keep the code general to accommodate the many BASIC dialects in use. A few dialects will require minor changes to the code for accommodation, and the following comments are provided to assist you in making those changes. For those dialects not able to handle LPRINT statements, you may use an OPEN statement followed by PRINT. Should you run into a situation where the dialect won't handle a variable containing two-letter alpha characters, try changing the

second letter of the variable to a number. The same change must be made to all like variables within the program. Each line of code containing an equation has been given a REMark statement to clarify the function or action being taken. You may disregard the REM statements when entering the code into the computer, although they can be helpful if you need to debug the program.

I've placed all INPUT statements on the right end of the line. For some dialects, the INPUT may be moved to the left end of the line, eliminating the PRINT command.

For the AC-voltmeter calculation, the program provides the option of loading the diode rectifier for meters having a sensitivity greater than 5 k/volt. When loaded by the program, the meter shunt and multiplier values are given for a sensitivity of 5 k/volt. The program assumes that you'll use silicone diodes as rectifiers, and that their forward-conduction voltage drop is 0.7 volt. If you use copper oxide, germanium, or other rectifier types instead, the D value in lines 1390 and 1400 should be changed accordingly.

The program is a series of function/calculation blocks driven from a menu. The menu provides a GOTO command call for the function selected. Upon completing the function, the program returns to the menu for your next action. I've also included printout samples from each block. You can use these samples to determine proper program operation. With the exception of the ohmmeter scale calculations and resulting printer output, all calculations and printouts are to the screen. The ohmmeter portion of the program provides the scale marking (calibration) as it applies to the relative coil-current value. The tabulated output makes the scale-marking task much easier.

Internal resistance is an important factor in most calculations. It should not be ignored until you know its effect on the results of calculations. The computer program requests an R_m value for nearly every function. If the value is unknown, use either a value from table 1 or enter 100 ohms.

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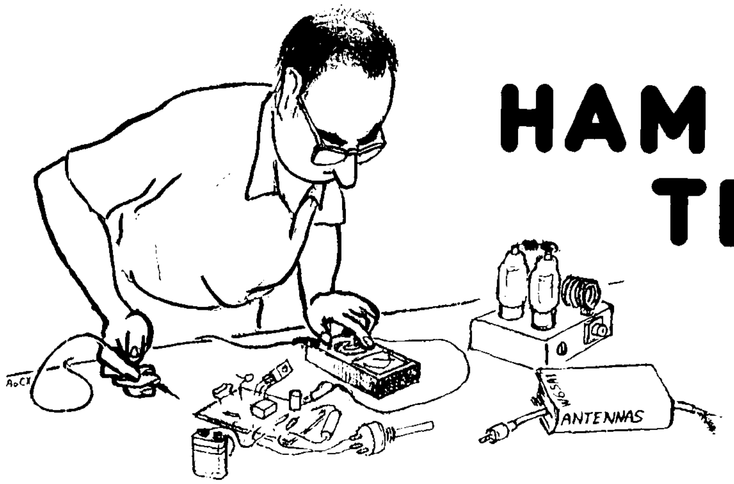
6. Harry E. Thomas and Carole A. Clarke, *Handbook of Electronic Instruments and Measurement Techniques*, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1967, Chapter 2.
7. Rufus P. Turner, *Basic Electronic Test Instruments*, Holt, Rinehart, and Winston, New York, 1961, page 254.

Article F HAM RADIO



HAM RADIO TECHNIQUES

Bill Orr, W6SAI

Antenna projects for spring

It's a little too early for serious antenna work in most parts of the country. But spring will soon be here and it's time to start thinking about all those great DX antennas you're going to erect! Here are some interesting antenna projects you readers have sent to me.

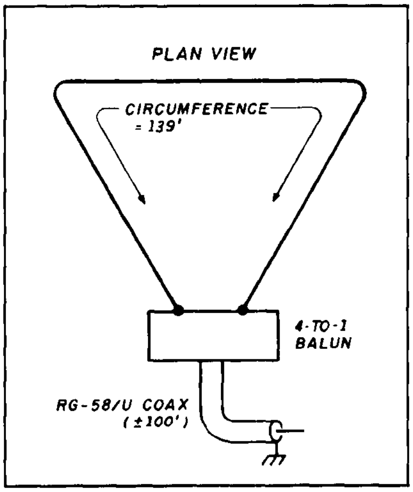
The AG9C horizontal loop antenna

I think the loop antenna has more interesting variations than any other! Bob Morrison, AG9C, has had excellent DX results with a full-wave horizontal delta loop that he uses on 40, 20, and 15 meters "as is," and with a tuner on 80, 30, and 10 meters (**fig. 1**). The only materials you need are about 139 feet of no. 14 copper-weld wire, a 4:1 balun, a few insulators, and a length of 50-ohm coax line.

Bob examined the antenna radiation pattern at 7, 10, 14, 21, and 28 MHz using the MININEC3 computer program with the Sommerfield-Norton option. He assumed a 20 foot height and poor ground ($k = 5$, and $\Gamma = 0.002$ siemens/meter). In general, Bob found that gain patterns are comparable to a dipole cut for each of these frequencies. One exception, he noted, is that the loop patterns are more omnidirectional than those of similar dipoles.

"The design is very forgiving," Bob comments. "Loop antenna patterns remain excellent when side lengths are unequal and/or the three corners have unequal heights."

FIGURE 1



Top view of the AG9C horizontal delta loop. Antenna works without tuner on 40, 20, and 15 meters. Tuner permits operation on 80, 30, and 10 meters.

Bob's observed SWR readings on the loop (taken through 100 feet of RG-58/U) are: 40 meters—1.55 at 7.0 MHz, 2.4 at 7.3 MHz; 20 meters—1.2 at 14.0 MHz, 1.7 at 14.35 MHz; 15 meters—1.38 at 21.0 MHz, 1.70 at 21.45 MHz; 10 meters—2.7 at 28.0 MHz, 3.7 at 28.5 MHz, 5.9 at 29.0 MHz, and 3.6 at 29.7 MHz.

You can move the minimum SWR point in the 10-meter band by changing the total length of the wire in the loop 6 inches at a time.

Bob says the loop can be used on 80 and 30 meters by adding an antenna tuner in the station. The input impedance of the loop on 80 meters is very high, as it is at a half-wave resonance. The mismatch at the balun causes high SWR and considerable power loss in the balun and coax line. Nevertheless, a tuner easily matches the feedline to the transmitter. Antenna radiated power is reduced, but adequate, over the CW portion of the 80-meter band.

The two-radial ground plane revisited

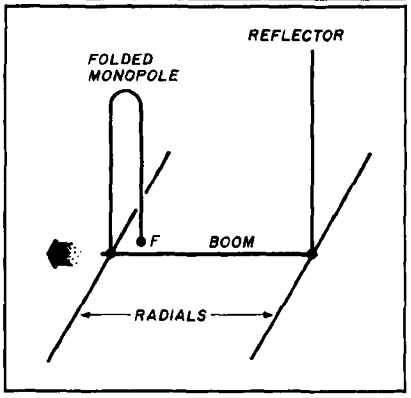
In my October column I mentioned that two radials seem sufficient for an elevated ground-plane antenna. Along this line, Gunter Hoch, DL6WU, wrote to me about a two-element "ground-plane Yagi" he observed atop a nearby United States Army depot. The antenna is shown in **fig. 2**. It consisted of a quarter-wave folded radiator and a reflector mounted over a pair of radials. He estimated from the size that it was cut for a frequency near the 2-meter band.

This is an interesting concept. With a couple of remote-controlled relays at the antenna it would be possible to switch quickly from a vertically polarized ground-plane Yagi to a two-element, horizontally polarized

conventional Yagi. The horizontal elements are cut to serve as a driven element and a reflector — just the ticket for a single antenna to work mobile stations (vertically polarized) and over-the-horizon DX (often horizontally polarized). I'll leave the details up to you!

DL6WU has submitted VHF Yagi data for inclusion in the *ARRL VHF Manual.*

FIGURE 2



Quarter-wave folded radiator is fed at F. Vertical elements are mounted above quarter-wave horizontal radials. (Courtesy DL6WU)

What is the correct radial length?

I mentioned some comments by Collin Stiteler, KE6VZ, about the correct length for ground-plane radials in my March column. Collin has raised another interesting question: "Many how-to-do-it articles on ground planes suggest that you make the radials something like 5 percent longer than the radiator. Why is this? Other articles call for radials equal in length to the radiator. If there are sufficient radials, they approximate a horizontal disc conductor. Should the radius of this disc be equal to, or 5 percent greater than the length of the radiator?"

Collin thinks that resonant radials should actually be a little shorter than the length of the radiator, not longer (as is occasionally stated), since the radials approach a "fat" conductor, or disc. The physical length of a "fat" conductor is less than that of a "thin" one for a given frequency, and Collin suggests that this rule should also apply to resonant radials.

This is an intriguing thought. I've always cut my radials to the same length as that of the radiator. Once I built a 21-MHz ground plane with radials 5 percent longer than the radiator. I couldn't notice any difference in operation or SWR measurements, as compared with an earlier, conventional ground plane. This leads me to think that radial length is unimportant (within 5 percent), at least in the HF region. Any comments on this question?

"Torching the Cat" and other exploits

I received a letter from "Doc" Sayre, N7AVK, who most assuredly deserves membership in the Antenna Experimenter's Club. Doc writes, "Fashioning a sky wire is truly exciting. I have loaded rain gutters on 160 meters (torching the cat in the process), fir trees on 15 meters (the nail gets hot and you shouldn't drive it in very deep for best results!), an all-band well casing about 160 feet deep, and an unusual buried run of two 4-0 insulated aluminum wires about 1/4 mile long that works amazingly well on 80 and 160 meters." He concludes, "If you're not thinking and improvising, then you're just taking up space!"

Good show, Doc!

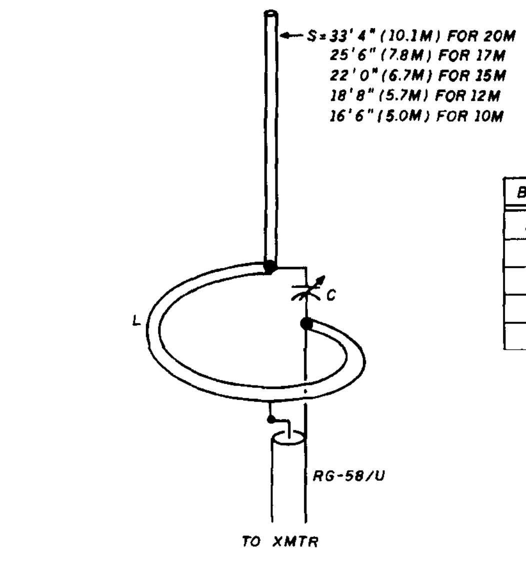
The gamma loop fed vertical antenna

In *The Radio Amateur Antenna Handbook*[1] I described an interesting DX antenna (shown in **fig. 3**). It consists of a half-wave vertical dipole fed at the bottom with a "ground independent" feed system.

The antenna shows about 1.8-dB gain over the classic ground-plane antenna and requires no radials. Feedline isolation is very good.

The feed system provides a match between the high-impedance end of the dipole and a low-impedance coax line. A parallel-tuned circuit will work. A low-loss design consists of a large, horizontally mounted single-turn coil in parallel with a high-voltage capacitor. The combination is resonant at the antenna's design frequency.

FIGURE 3



BAND	L (mH)	C (pF)
20	1.40	100
17	1.25	85
15	1.05	75
12	0.85	65
10	0.70	50

Vertical dipole fed with parallel tuned circuit at base. L-C circuit resonates at middle of band of choice. (Courtesy Radio Publications, Inc.)

John O'Brien, W2YYI, has solved the mechanics of making a waterproof tuned circuit and a high-voltage capacitor of inexpensive materials (see fig. 4). He makes the antenna and resonating coil out of soft, 1/2-inch, thin-wall copper tubing available from hardware and home improvement stores. The assembly is put together with a soldering torch.

In my original design, I achieved an impedance match by tapping the coax line on the single-turn inductor at the appropriate point. John, on the other hand, uses a gamma match system. I think his method is the better of the two. The gamma capacitor is made of a section of RG-8A/U coax cut to length and inserted in the copper tubing. The shield of the coax is attached to the shell (ground) of the coax receptacle. The center conductor is soldered to the gamma wire, which is tapped by a tubing clamp on the coil near the base of the antenna. The gamma wire is a length of PVC insulated house wire, or bare copper wire.

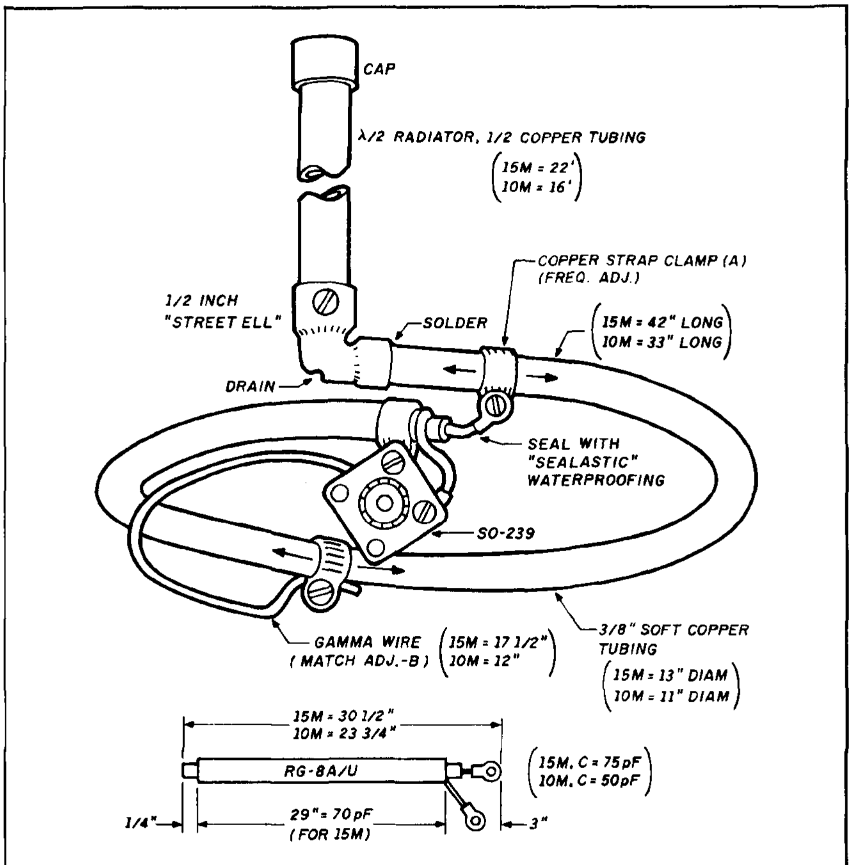
The antenna is adjusted for lowest SWR on the feedline by moving the two clamps along the coil. Clamp A is adjusted for frequency and clamp B is adjusted for the best impedance match. John notes that bending the gamma wire closer to, or further away from, the loop also affects the SWR.

Finally, John says you can make a "cheap and dirty" equivalent by substituting wire for the antenna and the loop, and making the capacitor out of a piece of double-sided pc board!

The W4TDI "Carolina Windom" array

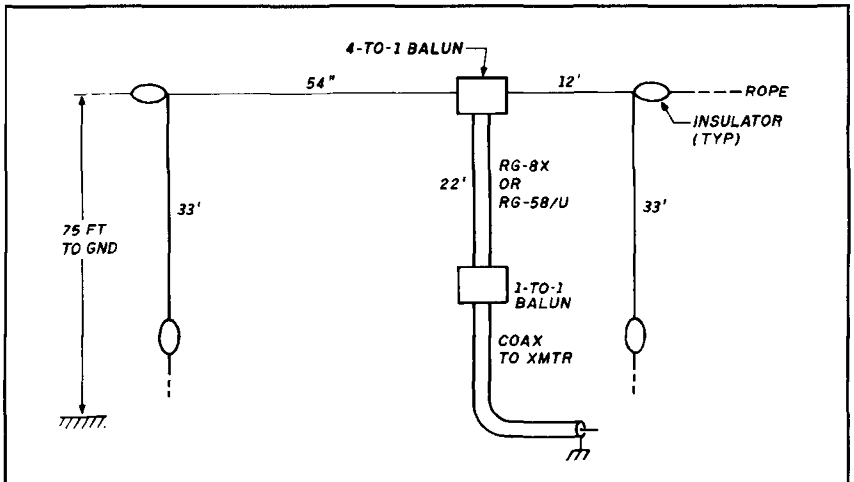
In the May 1988 column I discussed the Carolina Windom antenna, which seems to be enjoying some popularity. In brief, it's a multiband antenna fed with a stub and balun, which operates on more than one ham band. Ray Hoffman, W4TDI, making a virtue out of necessity, erected a version of the Carolina Windom between two trees only about 75 feet apart (see fig. 5). It was impossible to erect a 132-foot

FIGURE 4



Gamma loop-fed vertical for 10 or 15 meter bands. Capacitor is made of RG-8A/U coax and is slid inside copper tubing — Vaseline® helps!

FIGURE 5



The W4TDI version of the "Caroline Windom" antenna. Configuration works as broadside array on 20 meters with cloverleaf pattern. (See my column, May, 1988 for more data on "Carolina Windom" antenna.) A "Carolina Windom" kit maybe obtained from the Radio Works, Box 6159, Portsmouth, Virginia 23703, phone: 804-484-0140.

piece of wire on his property and keep it reasonably out of sight. He made his antenna 66 feet long and then dropped the two ends down vertically. The horizontal portion of the antenna is 75 feet above ground. He uses a feedline a half wavelength long on 75 meters, and the antenna works well on all bands between 80 and 10 meters without an auxiliary tuner.

W4TDI's antenna was, by chance, broadside to Europe. He found that, while working well on 75 meters in all directions, it did a great job into New York on 40-meter skeds with W2TBZ. But the big surprise was on 20 meters! Ray found he was getting exceptional signal reports on that band; Europeans said he had an "outstanding" signal. During the Russian DX contest he worked 26 stations in a row on the first call, in competition with the "big guns."

Ray felt these results were not in keeping with a conventional "all-band" antenna and he could only assume the excellent reports were caused by the antenna's unusual configuration. He generalized that the currents in the two vertical sections were in phase on 20 meters, resulting in two half-wave verticals in phase — separated by a full wavelength. This provides a cloverleaf pattern with two lobes perpendicular to the plane of the antenna and two lobes in the antenna plane. Gain is modest, perhaps 3 dB. But, because of antenna height, the angle of radiation is quite low.

Feeling he had stumbled onto something unusual, Ray built a 160-meter version of the antenna. It worked well on 160 meters, and results were very good on 75 meters. His most impressive results were achieved on 40 meters, and the antenna even worked on 20 meters — but not as well as the smaller version.

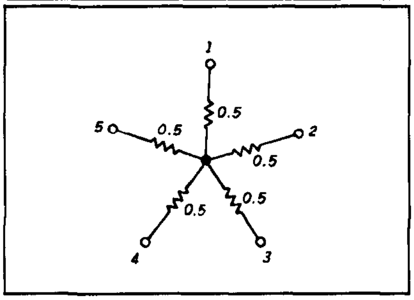
Ray is very enthusiastic about this simple antenna and is anxious to hear from anyone who tries it.

The Dead Band Quiz

Answers are still trickling in for the locomotive/hornet quiz given in the October column. Judging from the number of replies (over 400 to date), you all appreciate a challenge.

The quiz on parsing the National Anthem was a dismal failure. Either you all got an "F" in English composition and were too bashful to enter, or weren't interested in this quiz! The sentence structure contains the subject "you", the verb "can see" and the object "what". Kudos to Tim Bratton, K5RA; Joe Vogt, W5JF; Jack Wells, KØYPE; John Peak, KE6HS; Eric Nichols, KL7AJ; Harry Johnson, NV7K. All of you go to the head of the class!

FIGURE 6



Five 0.5-ohm resistors in star connection provide 1 ohm between any two terminals.

Last month's Dead Band Quiz

K4IHP's Black Box has five terminals. The resistance between any two terminals is 1 ohm. Figure 6 shows the connections within the box. Okay?

W3DZH's jar filled with transistors required a little brainstorming. If you have the March column in front of you, consider this:

A direct attack on the problem gets far too complex. It's actually easier to solve another problem instead, and then go back to the original.

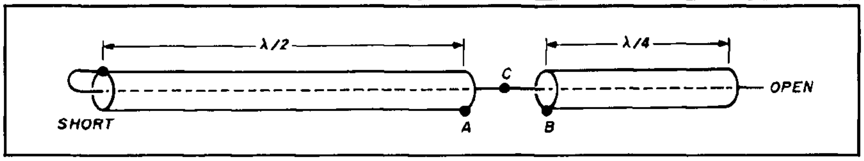
Consider the leftover transistors: one if dividing by 2, two if dividing by 3, three if dividing by 4, four if dividing by 5, five if by 6 and six if by 7.

The key to the solution is to ask yourself the question, "What if there had been one more transistor in the jar?"

Aha! If this is so, then the number of transistors would have been evenly divisible by 2, 3, 4, 5, 6, and 7. That number is the least common multiple of those intergers, $2 \times 3 \times 4 \times 5 \times 6 \times 7$, which is 420. But of course, that's not the way it was — the smallest number of transistors Our Hero had was one less than that, or 419 devices! Q.E.D.

Thanks to Joe Caffrey, W3DZH, for that brainbuster.

FIGURE 7



One length of coax an electrical half-wave length long is shorted at one end. A second piece a quarter-wavelength long is open-ended. The inner conductors are connected at C, but the outer shields are not. What is the impedance between the two outer shields (points A and B)?

A new Dead Band Quiz

Consider two pieces of RG-8/U coax cable connected as shown in **fig. 7**. One length is an electrical half-wave long, the other is an electrical quarter-wave long. Note that the inner conductors are connected at the joint A-B, but the outer shields are not. What is the impedance between points A and B (the two outer shields)? Send your QSL card with your answer to me at Box 7508, Menlo Park, California 94025. I'll give the solution in a future column. Good luck, and see you on the low end.

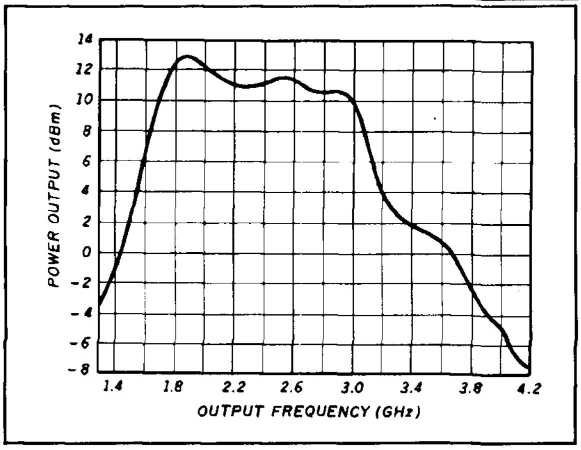
References

1. William I. Orr, W6SAI, and Stuart D. Cowan, W2LX, *The Radio Amateur Antenna Handbook*, Radio Publications, Inc., Box 247, Lake Bluff, Illinois 60044. (Also available from *HAM RADIO* Bookstore for $11.95, plus $3.50 shipping and handling.)

Article G **HAM RADIO**

THE WEEKENDER

FIGURE 1



Doubler power output for P_{in} = 7 dBm.

UHF GaAsFET doubler

To obtain low noise and high performance from a VHF, UHF, or microwave downconverter you need to use a high-level, low-noise local oscillator (LO). It's common practice to connect the output of a crystal oscillator directly to the LO terminals of a 2-meter converter. If the operating frequency is 145 MHz and the IF is 28 MHz, the crystal would operate at 117 MHz. My Oscar 13 downconverter operates this way.

On the other hand, a 432-MHz converter needs 10 dBm of 404-MHz oscillator power developed from a 101-MHz crystal followed by two frequency doublers, like those described by W1JR.[1] A 1296-MHz converter needs a 1152-MHz LO if the first IF is 144 MHz. For this you can use a direct-frequency synthesizer like the one described in my UHF VCO article.[2,3] A 2304-MHz converter with a 144-MHz IF requires a 2160-MHz LO. You can obtain this by multiplying the output of a 1080-MHz phase-locked loop (PLL) by 2.

More often than not, it's difficult to obtain sufficient LO power at 2160 MHz and above without the aid of step-recovery diodes (SRDs) and cavity resonators. Avoid this kind of complexity by using a GaAsFET frequency multiplier like the one I've described here.

Description

The UHF doubler provides over 10 dBm of output power anyplace in the band from 1800 to 3000 MHz, when driven from a 7-dBm signal in the 900 to 1500-MHz range. It's intended primarily for use as the LO in a downconverter but it has many other uses.

The performance of MESFETs and MMICs as frequency doublers up to 24 GHz has been investigated.[4,5,6] Varactors or SRDs, normally needed for multiplication, aren't required. The FET simply operates as a nonlinear amplifier; harmonics generated when the gate is driven into conduction are amplified by the drain circuit. The DC current requirements for a FET doubler are only about 28 mA.

I used a 2 to 10 GHz Avantek AT-12570 small-signal GaAsFET for my doubler; other types will work as well. While I limited my experimental circuits to about 3000 MHz, the device should operate up to 10 GHz or higher, if required. You may wish to cascade two of these doublers to provide a 10-dBm LO signal for a 3.4 or 5.8-GHz converter.

Performance

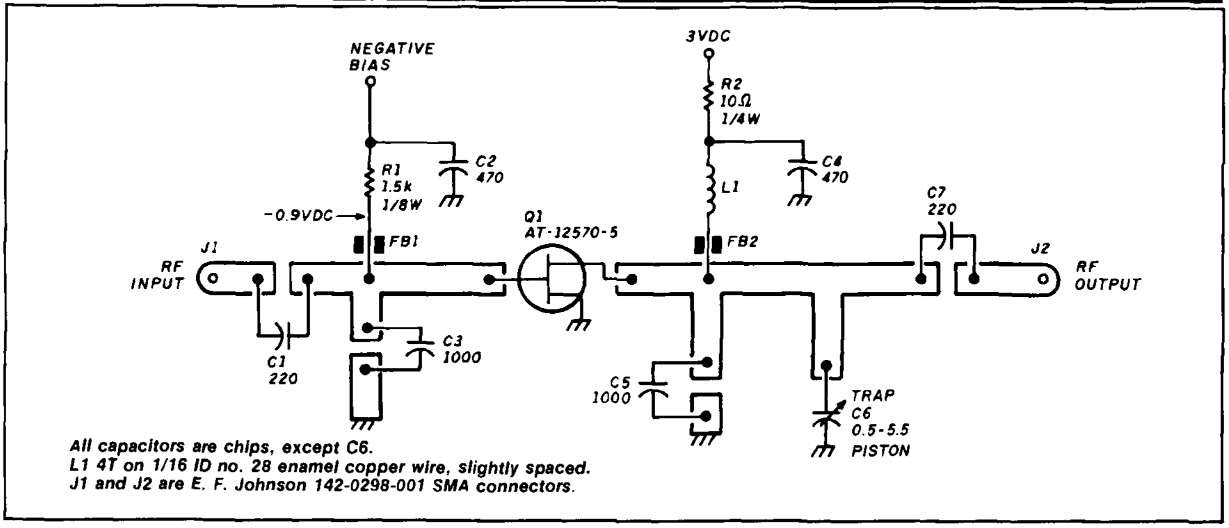
The input circuit of the UHF FET doubler operates at 1080 MHz, with the output circuit centered at 2160 MHz. However, performance is very broadband as shown in **fig.** 1.

Nominal I_{dss} is specified on the manufacturer's data sheet[7] as 80 mA. I operated the doubler with sufficient drive to achieve approximately 28 mA of average drain current. I_{dss} is highest at band center because the input circuit provides the best match to 50 ohms.

Feedthrough of the driving signal into the output is reduced only slightly by the filtering characteristic of the output microstrip circuit. Without additional filtering, the fundamental signal may be only 3 dB below the desired output level. I added a tunable trap circuit consisting of a 0.5 to 5.5-pF piston trimmer and a 1″ long, 1/8″ wide copper strap connected in series to ground, as illustrated in **fig. 2.** With the trap installed, fundamental output level was −40 dBm, while the third and fourth harmonics were 27 and 33 dB, respectively, below the desired signal. Since my requirement was for narrowband (fixed frequency) use, the trap was the obvious choice. For broadband operation, a bandpass or high-pass filter could be used instead.

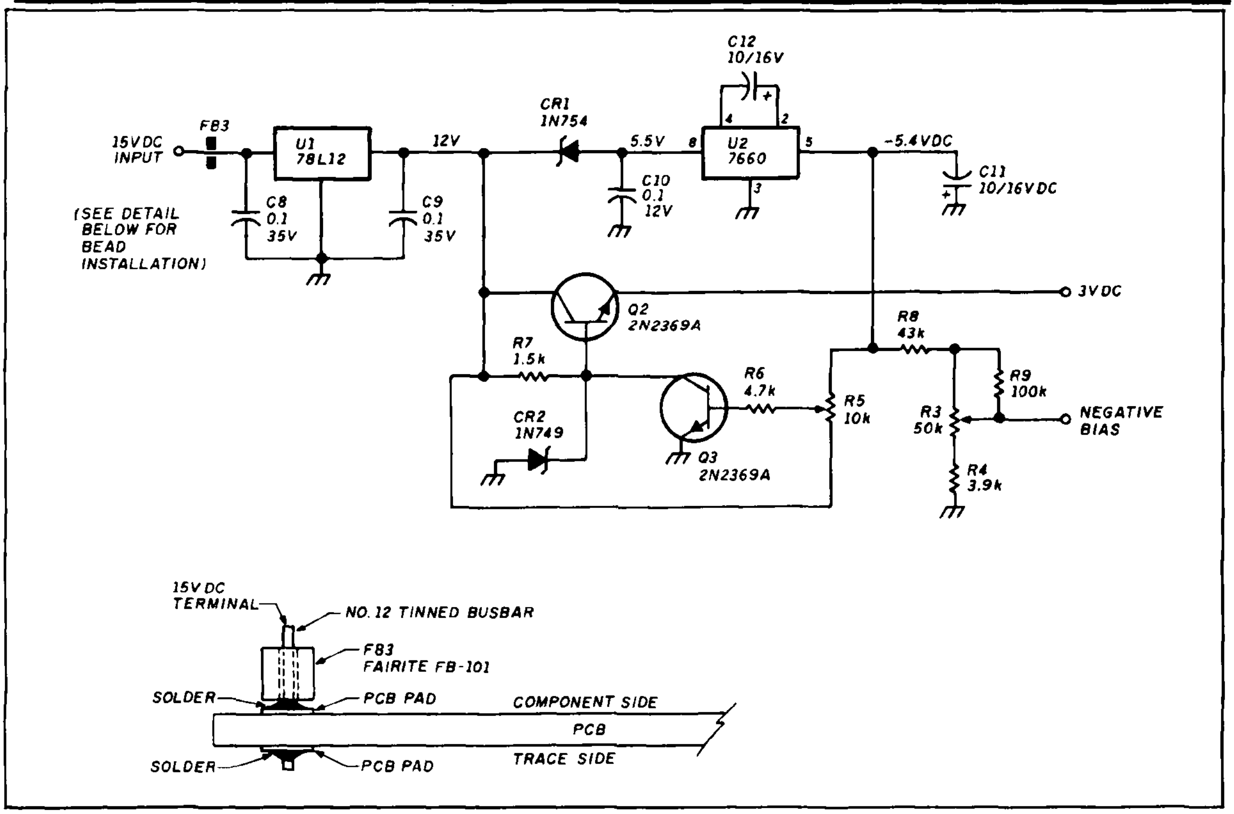
By Norman J. Foot, WA9HUV, 293 East Madison Avenue, Elmhurst, Illinois 60126

FIGURE 2



Schematic diagram, GAsFET doubler.

FIGURE 3



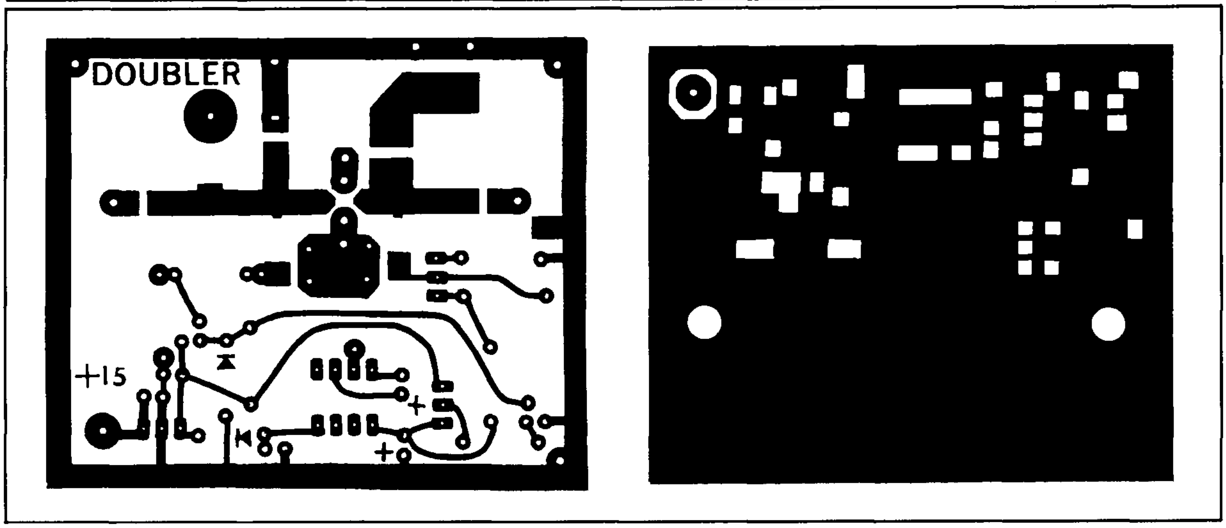
Schematic diagram, power supply/regulator.

Design

The FET doubler is etched on double copper-laminated epoxy fiber glass (G-10) pc board material. One side is used as a ground plane; the RF circuit traces are etched on the other side. Through grounds are made by passing no. 26 tinned copper busbar through ground holes and soldering on both sides.

I calculated the RF circuits with the aid of a computer program I developed for the 1296-MHz preamplifier published in *Ham Radio* Magazine.[8] I obtained

FIGURE 4



UHF GAsFET doubler artwork.

the scattering parameters from the manufacturer's data sheet. Despite the fact that the doubler isn't a "small-signal" device, it needed very little trimming to optimize its performance.

One of the doubler's important features is its stability. Because input and output circuits are an octave apart in frequency, there's little (if any) likelihood that feedback will cause instability. As a precaution against out-of-band feedback, I equipped both the gate and drain DC return circuits with ferrite beads.

The doubler schematic is shown in **fig. 2. Figure 3** shows the power supply. Artwork for the board is shown in **figs. 4** and **5**. Negative gate voltage is supplied from a common 12-Vdc source with an IC7660 voltage inverter. This is identical to the circuit I used in my 1296-MHz low-noise preamplifier article.[8] The circuit protects against FET damage should the negative supply fail.

Tune up

Before installing the FET, connect a 150-ohm resistor temporarily between drain and ground. Apply 15 volts to the DC input terminal and adjust trimpot R5 for 3.0 Vdc across the resistor. Remove the resistor and install the FET, taking the usual precautions against static charge.

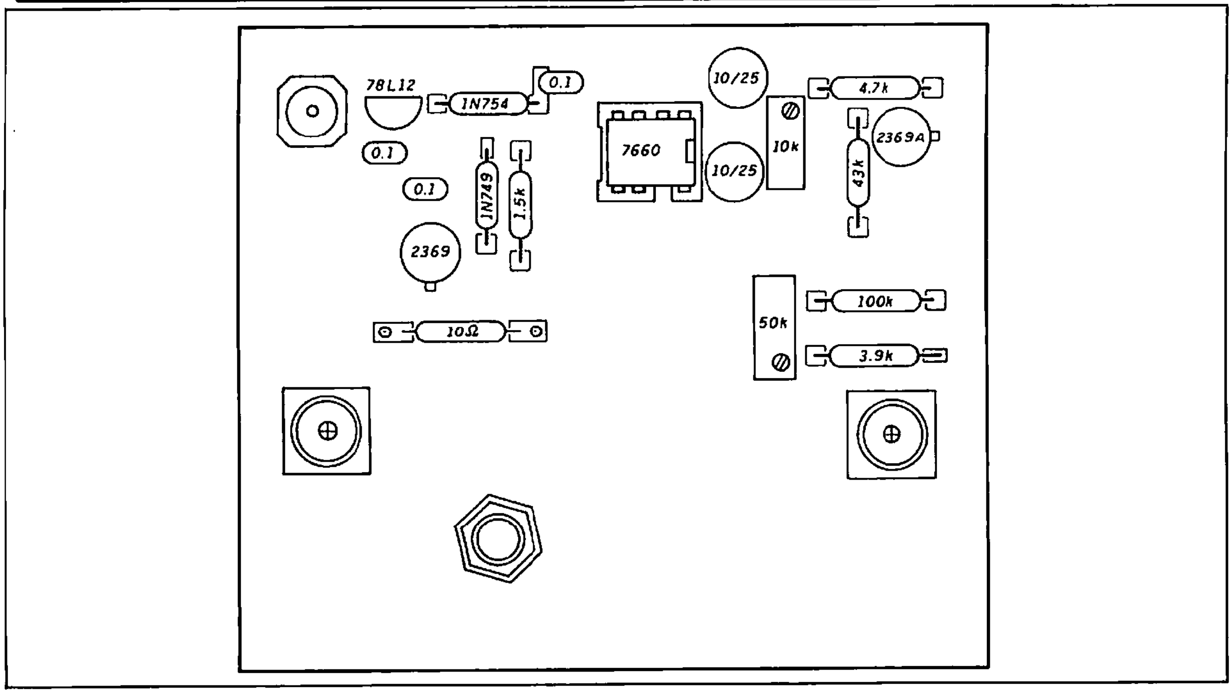
Next, apply 15 Vdc between the DC input terminal and ground. Then, with the input RF drive power shut off, adjust gate-bias pot R3 until the drain just begins to draw current. This isn't a critical adjustment, because when RF power is applied the drain current will increase to a value depending on the level of drive power. I suggest that you set the drive power to a level that produces a FET drain current of about 30 mA. Although higher drive levels will produce higher drain current and more power output, don't exceed $I_{dss}/2$.

PARTS LIST

Capacitors		
C1,C7	*220-pF chip*	
C2,C4	*470-pF chip*	
C3,C5	*1000-pF chip*	
C6	*Erie 0.5-5.5 pF*	*glass piston trimmer*
C8,C9	*0.1 35-volt tantalum*	
C10	*0.1 12-volt monolythic*	
C11,C12	*10/16-volt electrolytic*	
Potentiometers		
R3	*50 k*	*ten-turn trimpot*
R5	*10 k*	*ten-turn trimpot*
Resistors		
R1	*1.5 k 1/8 watt 5 percent*	
R2	*10 ohms 1/4 watt*	
R4	*3.9 k 1/4 watt 5 percent*	
R6	*4.7 k 1/4 watt 5 percent*	
R7	*1.5 k 1/4 watt 5 percent*	
R8	*43 k 1/4 watt 5 percent*	
R9	*100 k 1/4 watt 5 percent*	
Solid-state Devices		
U1	*78L12 regulator*	
U2	*ILC7660 inverter*	
CR1	*1N754*	
CR2	*1N740*	
Q1	*Avantek AT12570-5 GaAsFET*	
Q2,Q3	*2N2369A*	
Miscellaneous		
J1,J2	*EFJ 142-0298-001*	*SMA connector*
FB1,FB2,FB3	*FB-101*	*ferrite bead*
	pc board	
	eight-pin IC socket	

Note that the FET doubler includes a 10-ohm resistor in series with the drain circuit and 3-Vdc supply. Assess drain current by measuring the voltage across this resistor. The total current drain will be about 40 mA. You can control the output power by adjusting input drive level.

FIGURE 5



Component layout on groundplane artwork.

Conclusions

This simple but effective UHF GaAsFET doubler exhibits power gain. It provides over 10-mW output over nearly an octave band. As I suggested earlier, it may be possible to design the circuit for operation up to and beyond X-band* by using the same technique.[4] In my application, the doubler operates as the LO driving a balanced mixer in my 2304-MHz converter. If you have questions regarding this or similar applications, send a no. 10 SASE to the author.

References

1. Joe Reisert, W1JR, "VHF/UHF World," *Ham Radio*, March 1984, page 46.
2. Norm Foot, WA9HUV, "Low-Noise Phase-Locked UHF VCO-Part 1," *Ham Radio*, July 1986, page 23.
3. Norm Foot, WA9HUV, "Low-Noise Phase-Locked UHF VCO-Part 2," *Ham Radio*, August 1986, page 25.
4. Flavio Mantovani, "Active MESFET Multipliers Solve Low Signal Levels," *Microwaves and RF*, August 1984, page 129.
5. Jerry Hinshaw, N6JH, "MMIC Active Multipliers," *RF Design*, June 1988, page 64.
6. Jerry Hinshaw, N6JH, "MMIC Multiplier Chains for the 902-MHz Band," *Ham Radio*, February 1987, page 72.
7. *Transistor Data Sheet*, AT-12570-5, Avantek, Inc., 3175 Bowers Avenue, Santa Clara, California 95051.
8. Norm Foot, WA9HUV, "The Weekender: 1296-MHz Low-Noise Amplifier," *Ham Radio*, November 1988, page 60.

*5200–11,000 MHz. – *Ed.*

Article H HAM RADIO

THE HAM NOTEBOOK

Ferrite beads as antenna and tower guy isolators

One of the nagging questions about antenna systems is the possibility of pattern degradation resulting from current flow on guys, feedlines, and even the antenna support tower.

It's standard practice to cut the guy into pieces about a quarter wavelength long at the highest operating frequency and place strain insulators between the pieces. This cuts the coupling to a low value, effectively preventing appreciable current on the guy and stopping guy radiation. While the solution works, no one seems happy with it — largely because of fears of reduced strength, and the work it involves. Many try using a balun in the hope that it will solve any feedline problem, but tower radiation is almost always accepted "as is."

I found an easy solution to all of these problems. Simply use ferrite isolators, usually as beads. This technique was first described as a balun by Walt Maxwell, W2DU.[1] It's easily extended to any problem involving unwanted current flow.

It isn't necessary to have a perfectly isolated insulator. For example, suppose a guy section is a half wave long at the operating frequency. It would have a resistance at the current node of about 70 ohms. Placing enough beads on the guy at the high current point to increase the impedance to 700 ohms would cut the current to 1/10, and the power radiated by the guy to 1/100 of its original value. Even cutting the current to 1/3 of its original value would be helpful.

The exact number of beads you'll need depends on the operating frequency, and the size and type of the beads. (See the W2DU article, and the latest *ARRL Antenna Handbook* for design curves and data.) Anywhere from three to ten beads would be a good start, assuming you're using a material that has a fairly high μ at the operating frequency. Ten to 25 beads would be the most that are really beneficial.

It isn't necessary to cut guys (or coax feeders) loose to slide beads over the end on systems already in use. Split beads and shapes are available, and do nearly as well. (See the manufacturer's literature for information.)

Another possible solution is to use ferrite beads, instead of insulators, on the antenna itself. Suppose you want to use the top guy of the tower as a sloper. Put a number of beads at the top end of the guy close to the tower. Place more beads a half (or quarter) wave down the guy, and feed as for a normal sloper. (If you are using high power, you may find it necessary to use very low loss material for the first few beads. This will avoid heat problems.) Building slopers and delta loops in this way is a snap, even for towers which are already up.

Towers themselves are more of a problem, because of their size and parallel paths through the structure. For low frequencies, liberated TV yokes and sweep transformer cores are good — and readily available. They're usually so cheap (free) that you can be generous with placement. For best results, the ferrite should enclose each tower member, but it helps to just lay the ferrite close to the member.

You can calculate ferrite position by using the quarter-wave rule, or you can measure the guy/coax/tower resonance with a grid dip meter. The easy way is to make up a few special coils for the dipper. Each should be triangular in shape and about 20 inches on a side for low frequencies, or 6 inches per side for the higher bands. Solid Teflon™ insulated wire is ideal, but standard house wire works well. Use your frequency meter rather than trying to make a calibration curve.

To get close coupling, place the side of the triangle away from the dipper body close to the conductor. Tune for dips as usual. After you find the resonances, put some ferrite into the place that looks best, and check again. The dip may have disappeared, or shown a marked decrease. (If you can decrease the dip to at least 1/10 of its original value, you should be in good shape.) Sometimes moving the ferrite helps; at other times more ferrite is necessary. The goal is to have no appreciable dips at or close to operating frequencies. It's also a good idea to check harmonic frequencies, and to eliminate any such resonances if found.

After you've placed the beads, use weatherproof tape or silicone rubber to hold the ferrite in place and protect it from weather.

References

1. Walter Maxwell, W2DU, "Some Aspects of the Balun Problem," *QST*, March 1983, page 38.

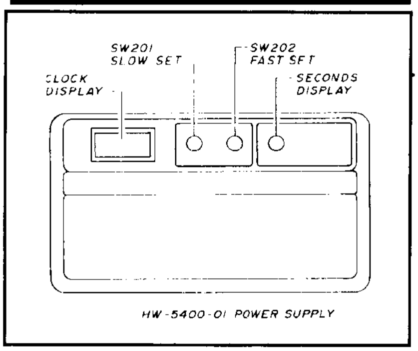
R. P. Haviland, W4MB

Improving clock setting for the HW-5400

I finally decided that there must be a better way to set the clock on my Heath HW-5400-01 power supply. My method of setting the time with a long pin or toothpick had to go! I also wanted to be able to set the clock to WWV to the nearest second. Here's my solution.

You'll need three small momentary SPST push-button switches. A set of Radio Shack no. 275-1574 or equivalent is fine. First, disassemble the power supply's front panel. Next, drill out the two holes on the front panel, grill, and escutcheon (they're labeled SW201 and SW202), and one extra hole an inch to the right of SW202 for the "seconds" display switch. See **fig. 1** for placement. (Remember to remove the metal switch springs from the display circuit board.) Mount the switches through the panel and grill,

FIGURE 1



Placement of holes for adding SPST switches to the HW-5400-01 power supply.

placing the escutcheon on last to cover the mounting nuts. Bend the tabs of the new SW201 and SW202 switches so they clear the circuit board. Connect one side of all three switches together and then to the 14-volt source by inserting the wire through the slot of SW202 on the circuit board. Solder the wire to the silver foil.

Solder the other tab of SW201 to the "hot" leg of R202 and the second tab of SW202 to the "hot" leg of R203. Now solder the other tab of the third switch (seconds display) to the circuit board pad of pin 34 of U201.

Pressing the seconds switch displays the "ones" minute digit and both seconds digits. Simultaneously pressing "seconds" and "fast set" lets you reset the seconds to zero without a minute carryover. To ensure an accurate setting to WWV, simply set the clock a minute ahead, press seconds, fast set, and hold the setting until WWV catches up — then release. Viola! Precise clock settings to the nearest second.

Dexter King, AB4DP

A tricky RFI solution

When the XYL said I was interfering with the broadcast receiver, I was stunned. After all, I thought I had solved just about every problem caused by my transmitter — even operating full power on all bands.

"Are you sure?" I said.

"Well, it has been more than 50 years since you tried to teach me the code, but I can still follow the key clicks well enough to make out W2YW. And, that new renewal you got from Gettysburg says you are W2YW — so, yes, I am sure."

The receiver was an eight-band Federal Model 8B1000 and it was picking up key clicks on a few spots in the broadcast band. One of them was at 1390 kHz — the QRG of one of her favorite stations to sleep by, because it's an all-talk station. The interference occurred when I operated on 15 meters, and with all the activity now on 15, I simply had to find a solution.

First, I wound some no. 24 dual zip-cord on a 1/2″ ferrite rod 5″ long, slipped it under the battery pack compartment, and wired it into the AC line. This was no help. I was on the right track but headed in the wrong direction.

Next, I tried a Kenwood R2000, using a piece of bell wire thrown out the window for an antenna. No sign of any key clicks, but the wife turned that solution down saying it had "just too many buttons." Now what?

With the Federal receiver switched to battery and the line cord pulled, it still picked up the key clicks.

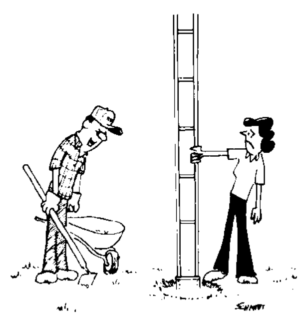
The solution was simple, but took a little doing to find. An extension cord was plugged into the other half of the wall duplex outlet where the offending receiver was connected. This fed two desk lamps and an electric clock. Pulling the extension cord killed the click. Evidently the two lamps, extension cord, and clock made up an antenna that was picking up the 15-meter signal and creating a more intense RF field around the receiver. The loop stick in the receiver picked this up.

I didn't have any more ferrite material, so I dug through my junk and found an RF high-voltage transformer from an old, old TV set. I cut off all the windings with a hacksaw and wound another extension cord around three sides of the ferrite form. I plugged the makeshift choke into the wall outlet, plugged the line cord feeding the lamps and clock into the output end of the choke, and all my clicks were solved. As I said earlier, I was on the right track with the line filter. The trouble was, I was in the wrong place!

Article I **John Labaj, W2YW**

FEBRUARY WINNERS

Congratulations to Teddy Coggin, WD4CWV, our February sweeps winner and John Pivnichny, N2DCH, author of February's most popular WEEKENDER — "High-Impedance Rotary Step Attenuator." Both will receive a copy of *The Radio Handbook* by Bill Orr, W6SAI. To enter for April's drawing, send in the evaluation card bound into this issue, or submit a WEEKENDER project. You could be our next winner! *Ed.*



WELL NOW - ALL YOU HAVE TO DO IS HOLD 'ER LIKE THAT UNTIL THE CONCRETE SETS!

A REMOTE DRIVER/ CONTROLLER
FOR A TWO-ANTENNA SYSTEM

By William L. Schreiber, NH6N, 73-4327 Imo Street, Kailua-Kona, Hawaii, 96740

Set azimuth and elevation from the comfort of your shack

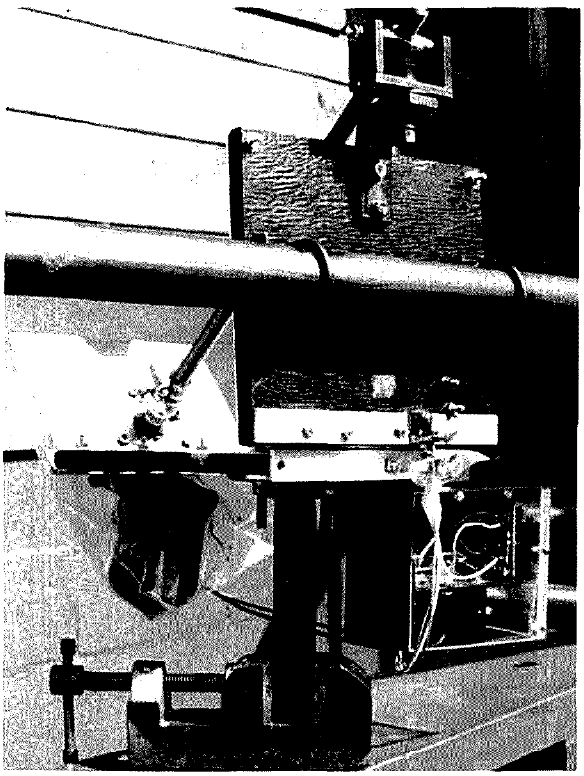
This article describes a simple light-duty, dual-rotator assembly that allows you to set the azimuth and elevation of two lightweight, low wind load antennas by remote control. It's ideally suited for satellite operation, with uplink and downlink antennas each requiring different orientation.

A variety of rotators — including one that combines azimuth and elevation in a single housing — are readily available. Because I wanted an azimuthal rotator with a silent control box, I chose a Winegard TV rotator that cost about $40. For elevation, I decided to use the approach that had been so successful in my solar panel sun tracker.[1] That plan involved using a 12-volt DC Mazda windshield wiper motor (about $3 at the junkyard) and a 2-foot length of threaded 1/2-inch steel rod. A 3-inch flexible coupling was used to compensate for mechanical misalignment. I tried using a 3-inch piece of auto heater hose and two hose clamps initially, but the combination of sun and mechanical stress caused this arrangement to fail after about six months.

The elevation assembly consists of two 6 × 8-inch pieces of 1/4-inch aluminum plate connected by a 1-inch piano hinge. A 5-foot long × 2-inch diameter fiber glass rod (manufactured by KLM) is used as the boom and an antenna is mounted at each end. The boom is rotatable through 90 degrees with a lead screw mechanism like the one in the solar panel setup.[1] The other plate (which becomes the base) has a floor flange bolted to it; a 2 foot length of 1-inch water pipe is screwed into the flange. The pipe is then attached to the Winegard rotator which is bolted to the mast.

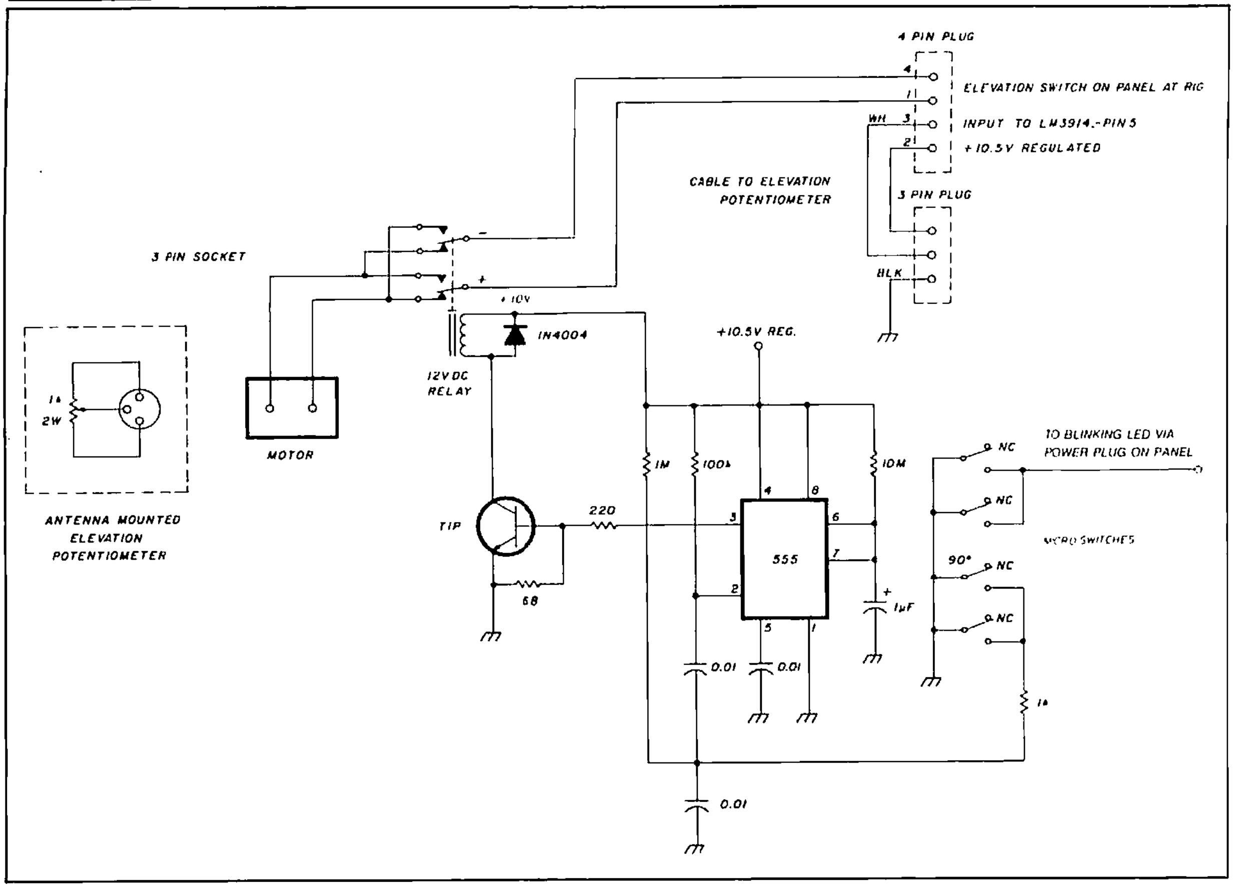
The windshield wiper motor is bolted to another 6 × 8-inch piece of 1/4-inch thick aluminum plate which is attached to the opposite side of the base plate by another 1-inch piano hinge. (See **photo B**). This assembly permits the motor to move up and down as it turns the lead screw and offers further compensation for mechanical misalignment (see photos).

PHOTO A



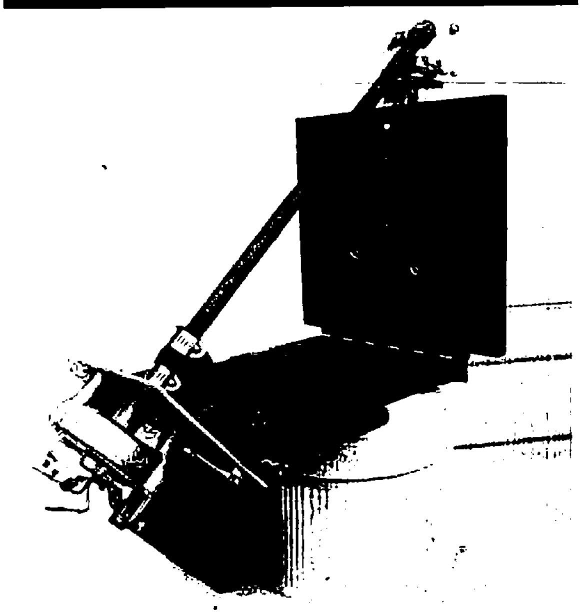
Left front view of elevation drive at maximum elevation showing fiberglass rod support for antenna. Also shown is electronics box with limited switch control circuit.

FIGURE 1



Antenna mounted part of elevation control. VHF/UHF antenna.

PHOTO B

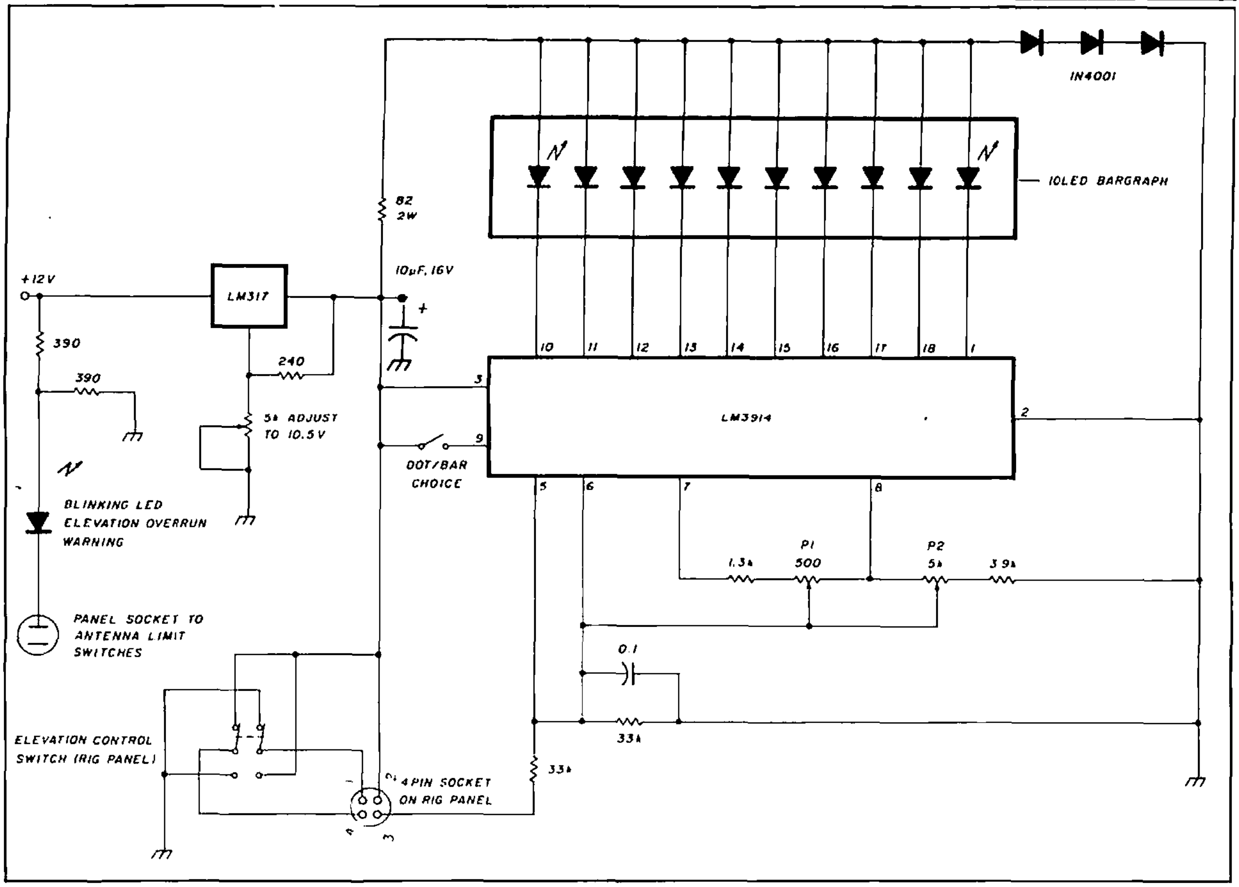


Side view of elevation drive with windshield-wiper motor attached.

It takes about 3 minutes for the antennas to go from 0 to 90 degrees elevation. There's a potential problem here, however, with the antennas not visible from the station: they could be inadvertently driven below 0 degrees or above 90 degrees, and this could destroy the system. To prevent this, and to make the system as foolproof as possible, I installed two Microswitch limit switches at each extreme of elevation travel. One causes an LED (RS-276-036) to blink in the shack just before the whole system hits bottom or top; the other activates an antenna-mounted timer and relay that automatically reverses the motor for 30 seconds.

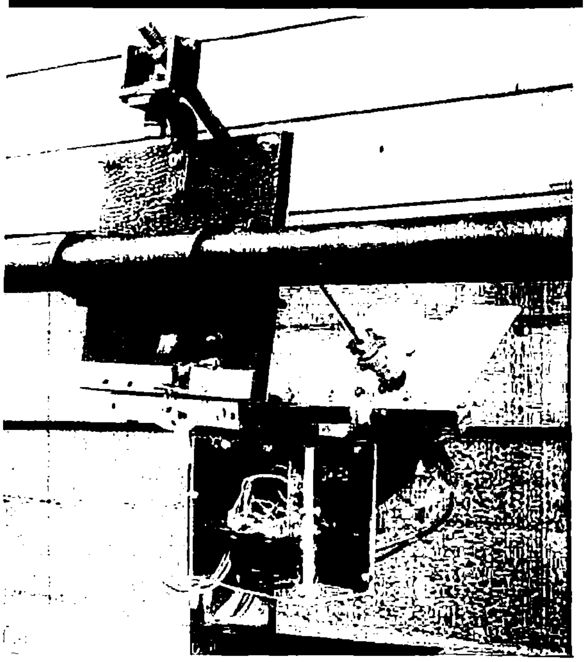
A circuit built for this purpose is shown in **fig. 1**. A manually-triggered monostable that uses an LM555 is employed. When the first limit switch is activated, a ground is placed on a blinking LED in the station, signaling the operator to reverse the motor control switch promptly. If the operator doesn't respond quickly enough, a second switch is activated, powering up the timer and causing the relay to change state and reverse the motor. This continues for about 30 seconds, which should be plenty of time for the operator to recognize the error. The 555 times out, the relay releases, and regular motor control can now occur.

FIGURE 2



Elevation control + indicator.

PHOTO C



Right front view of elevation drive at maximum elevation showing fiberglass rod support for antenna. Also shown is electronics box with limit-switch control circuit.

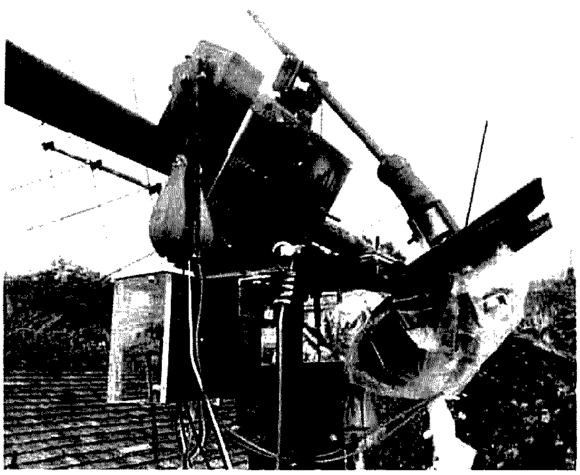
The whole assembly is bolted to the lower antenna mounting plate and encased in a 3 x 5 x 2-inch weather-tight plastic box.

elevation angle indicator

This design provides a simple, reliable elevation angle indicator. Instead of choosing an old-fashioned analog meter, I opted for a bank of LEDs.

A nice circuit for this indicator (**fig. 2**) is one originally intended for use as a voltmeter and described in the *National Linear Data Book.*[2] The driver IC is available from Radio Shack (No. 276-1707) or other vendors. The LEDs, also from Radio Shack (276-081), come in a nice ten-element block. Controls P1 and P2 adjust the point at which the bottom and top LEDs activate. It's necessary to set these alternately as the antenna is elevated and depressed, so that the array starts at 0 degrees rather than 90 degrees, and also so that the whole array is lit at maximum elevation and unlit at minimum. This takes a bit of juggling back and forth, as well as setting the antenna pot so that it covers a full 90 degrees before it hits the stops. Doing this isn't as complex as it sounds, but does require two people: the operator in the station and a helper at the antenna.

PHOTO D



Left rear side view of antenna drive system. Elevation pot arm with lead weights is visible at top.

PHOTO E

DC control panel, column of LEDs and "Stop" LED used for elevation indication on right side.

All that's needed to actuate the circuit is a variable source of DC representing elevation angle. A clever way to do this appeared in the Amateur press several years ago.[3] A good-quality linear potentiometer is mounted in a waterproof box on the elevation part of the antenna. The potentiometer shaft has a 1/2-pound lead fishing weight attached; this keeps the shaft vertical no matter what elevation angle occurs. Feed the pot with 12 volts DC on one end, ground the other, and pick off the elevation-dependent voltage from the center tap. This goes to pin 5 of the LM 3914 driver IC, where it's conditioned and trimmed to light the LEDs progressively.

I opted for ten LEDs to indicate 9 degrees each, which might be too coarse for a purist. It's a simple matter, however, to cascade as many LEDs as desired; a circuit for this purpose is included in reference 2. While the antennas have a rather narrow beamwidth, in fact, it's still much wider in practice than the 9 degrees represented by a single LED.

My station operates almost entirely from a 12-volt storage battery kept charged by a photovoltaic (PV) panel. There's no reason why you can't get by with regular 120-volt service.

References

1. William L. Schreiber, "Complete Solar Power for Your Ham Station," *ham radio*, December, 1984, page 14.
2. *Linear Data Book*, National Semiconductor Corporation, 1982, pages 9-163.
3. George Chaney, W5JTL, "An Inexpensive Elevation Indicator," *ham radio*, June, 1985, page 67.

Article J **HAM RADIO**

THE CONVOLUTED LOOP

Here's a small, very efficient, low-band radiator

By **Ted Hart, W5QJR**, P.O. Box 334, Melbourne, Florida 32902

A small loop antenna can provide excellent performance for both transmitting and receiving.[1] The convoluted loop in **fig. 1** is a single conductor configured to produce two orthogonal loops. This results in an antenna with high performance, small size, and an almost ideal radiation pattern for operation at the low end of the HF spectrum. The antenna is designed for mounting at ground level over a small counterpoise; its height is less than 0.04 wavelength.

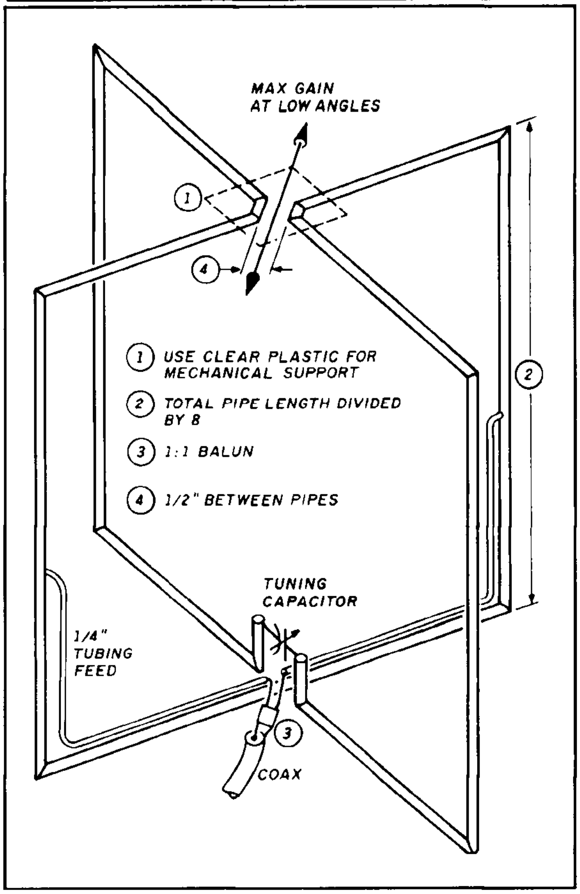
Theory

Table 1 lists the equations developed to define the convoluted loop. The computer program at the end of this article is based on these equations.

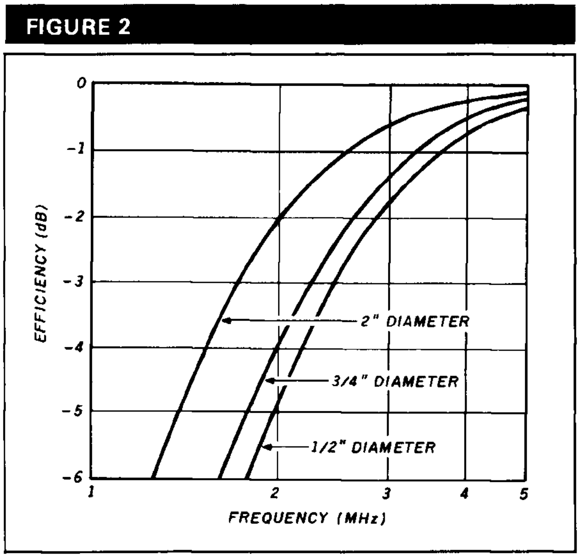
The efficiency of any antenna is defined as the ratio of the radiated power to input power. This is conveniently expressed as the radiation resistance divided by the sum of the radiation resistance plus loss resistance. Because small antennas are characterized by low radiation resistance, efficiency is a major concern. On the other hand, large antennas have a high radiation resistance compared with the loss in the antenna conductor.

The radiation resistance for a small loop antenna is dependent on the area enclosed by the conductor and the operating frequency.[2,3,4] The antenna will become self-resonant if the conductor length is greater than 1/3 wavelength due to distributed capacity. This sets the maximum length of the conductor. The equations

FIGURE 1



Physical layout of the "convoluted loop."



Effect of conductor diameter on efficiency — total conductor length is 80 feet.

TABLE 1

Equations for a Convoluted Loop Antenna.

Efficiency of an antenna	$\epsilon = R_R/(R_R + R_L)$
Radiation resistance—ohms	$R_R = 3.38 \times 10^{-8}(F^2A)^2$
Total area—square feet	$A = 4(S/8)^2$
Loss resistance—ohms	$R_L = 9.96 \times 10^{-4}\sqrt{F}(S/D)$
Q	$Q = X_L/(2(R_R + R_L))$
Bandwidth—MHz	$BW = F/Q$
Inductance—henries	$L = 1.13(5.6624 \times 10^{-7} \times S^{0.6984})$
Inductive reactance—ohms	$X = 2\pi FL$
Distributed capacity—pF	$CS = 1.1374 \times 10^{-11} + 4.684 \times 10^{-13} \times S$
Tuning capacitor—pF	$CT = 1/(2\pi F)^2L) - CS$
Voltage across tuning capacitor	$VC = \sqrt{PQX}$
Plate spacing for CT—inches	$SC = VC/75000$
F—operating frequency—MHz	
D—conductor diameter—inches	
S—conductor length—feet	

reflect the fact that a single conductor forms two loops for this antenna. When a reflecting screen is placed under the loop, the effective area of the loop doubles because of the image concept. In the equation for area, the multiplier of 4 covers both the dual loops and their reflected images. For a square loop design, each side of one loop is the total conductor length divided by 8. The maximum area is achieved for a given conductor length when the conductor is circular. The area is reduced to 87 percent for an octagon and to 78 percent for a square, when compared with a circle. For mechanical simplicity, a square loop with a reflecting screen is used for the example in this article.

The small loop area results in low values of radiation resistance. The primary component of loss resistance results from the loss in the conductor; a small component is due to ground loss, which will be discussed later. Therefore, a low-loss conductor is required. To minimize loss, use copper pipe. The equation for loss resistance includes skin effect loss for copper pipe, which varies as a function of frequency.

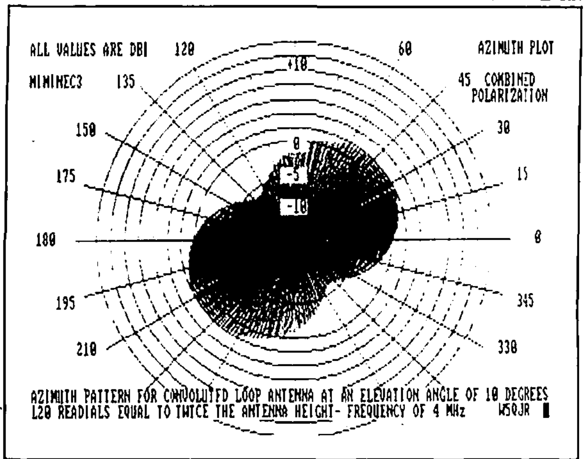
Although efficiency is a major design parameter for any antenna, the Q of the antenna must be considered for small high-efficiency ones. Large diameter conductors allow the Q to be sufficiently high to affect the instantaneous bandwidth in such a way that it may be too narrow for the type of modulation desired. High Q is also an indication of very high voltages across the tuning capacitor. Small conductors, which have higher loss resistance, will produce lower Q and lower efficiency. For this reason it's necessary to make tradeoffs in the design of the convoluted loop for a particular application. For most applications in the HF frequency range, 3/4-inch copper pipe (9/10 inch outside diameter) is a reasonable compromise. **Figure 2** presents efficiency versus frequency for various size conductors, indicating only small improvements for larger, more expensive, copper pipe.

The equations for inductance and distributed capacity are based on data derived from convoluted loops of varied sizes at various frequencies — primarily between 1.8 and 10 MHz. The tests were performed on the latest version of MININEC3.[5] They have been derived for 3/4-inch copper pipe and square loops only. Once the inductance and distributed capacity have been calculated, the convoluted loop is considered a simple resonant circuit. This lets you calculate the inductive reactance and the tuning capacitor value. Multiply the equation for inductance by a value of 1.13 to cover the effect of the matching network. The matching network is an autotransformer type of match, having both series and mutual inductance.

You can calculate the Q of the antenna once you know the inductance and resistance. Divide the standard equation for Q by 2 to include the effect of the transmitter/receiver loading; it's the system Q that is important, not the Q of the antenna as a stand-alone component. The calculated bandwidth of the antenna is the ±3 dB bandwidth, assuming a perfect match (VSWR = 1.0:1) at resonance. At the 3-dB frequencies the calculated VSWR is 5.1:1 and the resistance and reactance values are equal, resulting in a 45-degree phase shift of the equivalent resonant circuit.

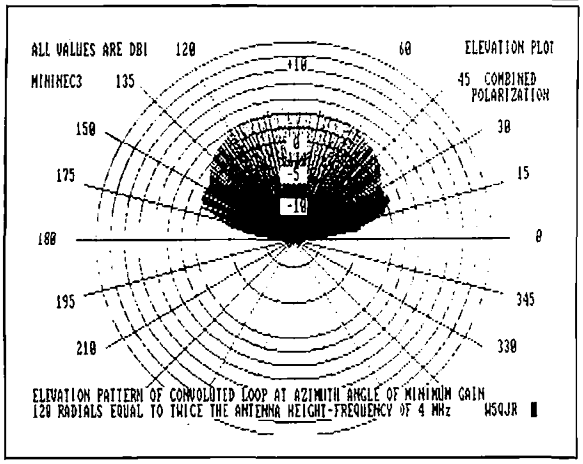
The voltage across the tuning capacitor is a function of the transmitter power and the antenna impedance. Despite the fact that the voltage can be very high, it's not excessive for available tuning capacitors. Although vacuum variables are preferred, the spacing for an air variable is calculated based on 75,000 volts per inch spacing.

FIGURE 3



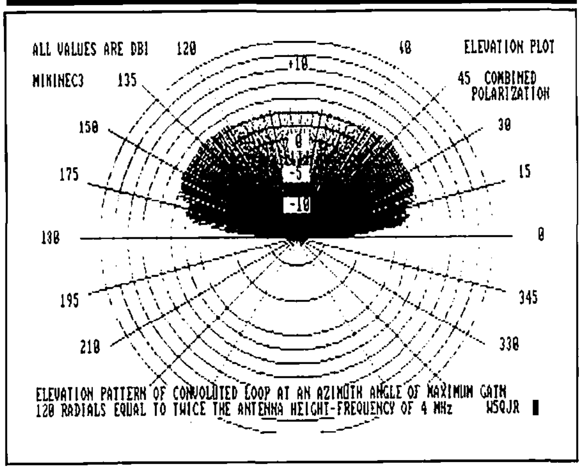
Azimuth pattern for the convoluted loop at an elevation angle of 10 degrees. Pattern was made at 4 MHz with 120 radials equal to twice the antenna height.

FIGURE 4



Elevation pattern of convoluted loop at the azimuth angle of minimum gain. Pattern was made at 4 MHz with 120 radials equal to twice the antenna height.

FIGURE 5



Elevation pattern of convoluted loop at an azimuth angle of maximum gain. Pattern was made at 4 MHz with 120 radials equal to twice the antenna height.

Antenna evaluation

I've drawn some conclusions based on experimental results of the convoluted loop, and from data calculated by MININEC3.

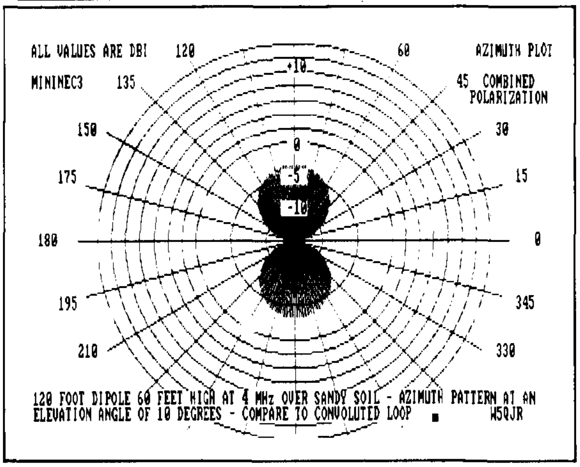
The antenna is easy to build. Simply cut sections of copper pipe and join them with copper elbows. Pieces of clear plastic in the center at the top and bottom provide good insulation and mechanical rigidity. The length of the longer pieces of pipe are equal to the total conductor length divided by 8. Cut the shorter pieces to length at the top to allow 1/2 inch between the 90-degree bends, which are made of two 45-degree elbows joined with a short section of pipe. Remove a short section of pipe at the bottom for installation of the tuning capacitor.

You must solder or braze each joint in the antenna to minimize joint resistance. Use a low-loss tuning capacitor (a vacuum-variable, for example). If you connect the loop ends to the two stators of an air variable split stator or butterfly capacitor, placing them in series with RF currents flowing through the rotor, there is no loss due to wiper contacts. But you *must* weld or braze all pieces of the capacitor. The typical variable capacitor has plates installed and held in place by mechanical pressure only; this results in high resistance at each mechanical joint. The high loss will make the loop inoperable. You can correct this deficiency by removing all aluminum plates and replacing them with copper or double-sided pc board material. Then you can use straps to bond the plates together and provide connection to the loop conductor.

Although you may tune the antenna over a wide frequency range, it must be tuned to the operating frequency because of its narrow instantaneous bandwidth. Do this by using a stepper motor to rotate the shaft of the variable capacitor. The unit I prefer has a 7.5-degree step angle and includes a small 300:1 gear head reducer. This motor is manufactured by Hurst Manufacturing in Princeton, Indiana. The part number is 3004-001. They also produce an integrated circuit (part no. 22001) that makes an ideal driver, with the simple addition of a few components and a power supply. Reduce the gear ratio for a vacuum variable, because numerous shaft revolutions are required to vary the value of capacity from minimum to maximum.

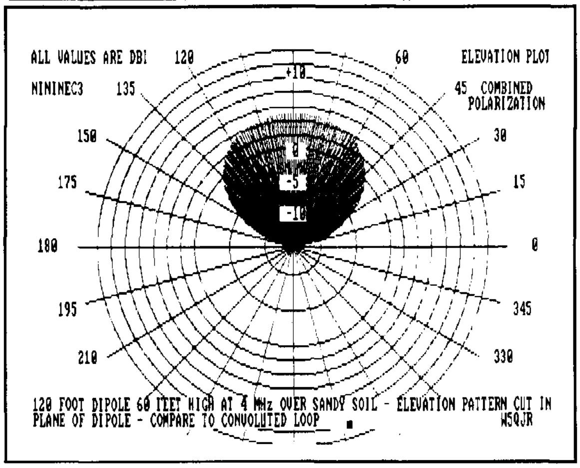
You must feed the convoluted loop as a balanced antenna. A 1:1 balun transformer is required for 50-ohm coax feed. Make the feeders from 1/4-inch copper tubing wrapped with black plastic electrical tape for insulation. Each feeder is the length of one of the

FIGURE 6



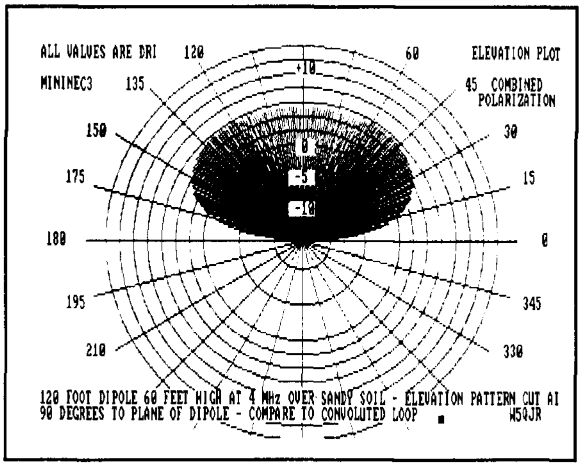
A 120-foot dipole at 60 feet for 4 MHz. Azimuth pattern at an elevation angle of 10 degrees over sandy soil.

FIGURE 7



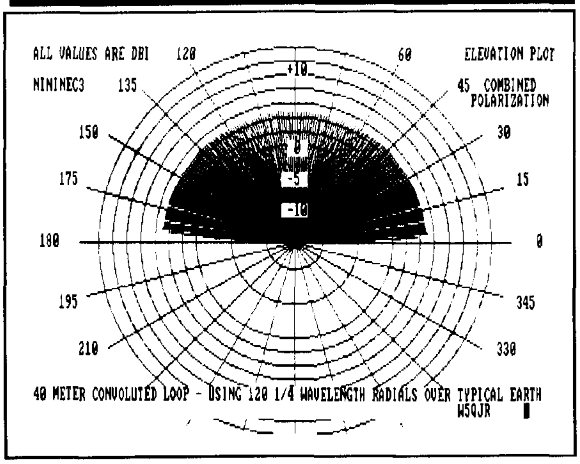
A 120-foot dipole at 60 feet for 4 MHz. Elevation pattern cut in plane of dipole over sandy soil.

FIGURE 8



A 120-foot dipole at 60 feet for 4 MHz. Elevation pattern cut at 90 degrees to plane of dipole over sandy soil.

FIGURE 9



A 40-meter convoluted loop using 120 quarter-wavelength radials over typical earth.

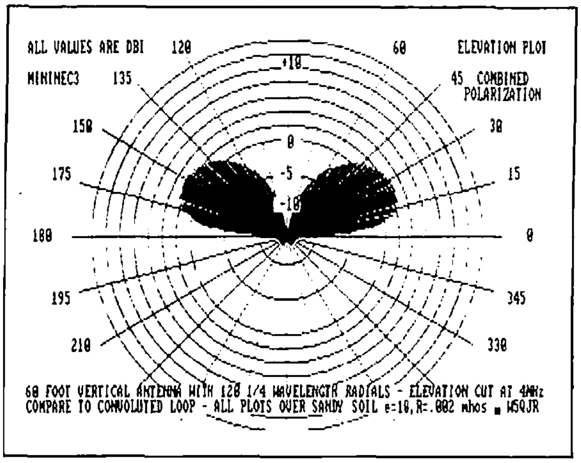
long sides of the loop, formed to the inside of the loop antenna orthogonal to the loop that includes the tuning capacitor. The spacing between the feeder and loop conductor and the length of the feeders determine the feedpoint impedance. Once you've soldered the ends of the feeders, bending the feeders to vary the spacing will let you achieve a very low VSWR. This is only one of many ways to feed this antenna; I find it the most convenient.[6]

The loop develops a very high magnetic field. If the loop is placed close to ferrous metal, like reinforcing material in concrete, some rain gutters, or antenna towers, RF energy will be coupled into the ferrous material. This reflects a change of impedance into the loop, increasing its loss resistance and decreasing its efficiency.[7]

Because of its magnetic properties, the convoluted loop isn't sensitive to electrostatic fields (the major cause of reception of man-made noise). You'll notice a significant improvement in signal-to-noise reception in noisy areas. In theory, the value is 26 dB. As a result of the high Q, the antenna serves as a preselect filter prior to the receiver. This improves reception in the presence of impulse noise, especially from lightning during thunderstorm activity.

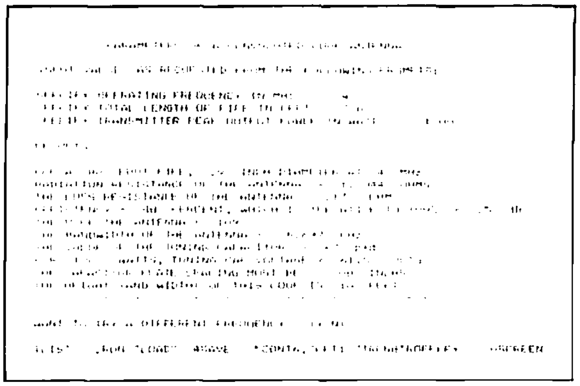
Earlier I suggested that the antenna should be used in conjunction with a counterpoise. **Figures 3**, **4**, and **5** present radiation patterns derived from MININEC3 for a 10-foot tall convoluted loop operating at 4 MHz with a counterpoise made of 120 radials — each having a length equal to twice the height of the antenna. Because you're dealing with the reflected energy only (not conducted energy), the radials don't need to be connected to the loop. All patterns presented in this article are over a ground with a dielectric constant of 10 and a conductivity of 0.002 siemens, representing

FIGURE 10



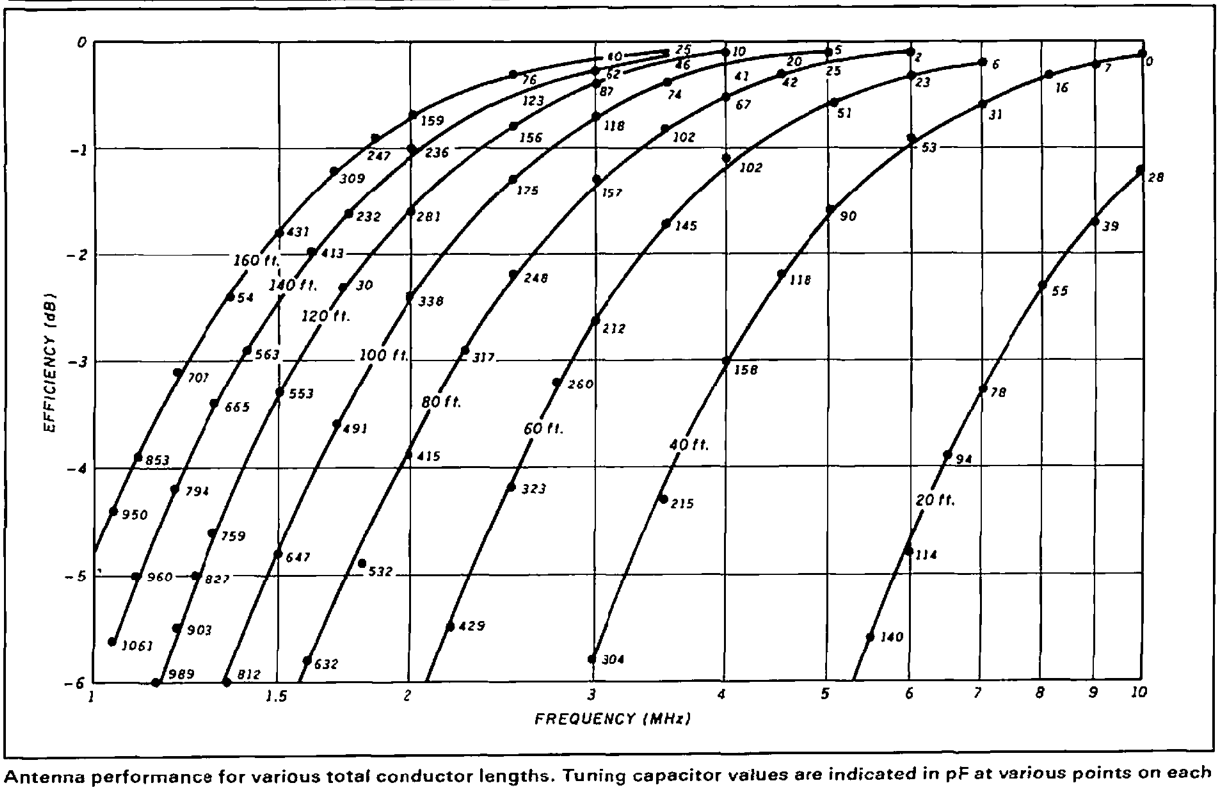
60 foot vertical antenna with 120 quarter-wavelength radials. Elevation cut at 4 MHz.

FIGURE 11



Example of the prompts encountered when running the program for determining the parameters of a convoluted loop.

FIGURE 12



Antenna performance for various total conductor lengths. Tuning capacitor values are indicated in pF at various points on each conductor's line.

sandy soil in Florida. The patterns are based on antennas with perfect conductors. Actual patterns can be determined by reducing the pattern gain by the efficiency calculated for a particular size antenna. **Figures 6, 7,** and **8** are presented for comparison based on a dipole over the same ground. **Figure 9** is a convoluted loop at 7 MHz over 120 1/4-wavelength radials, and **fig. 10** is a 1/4-wavelength vertical with 120 1/4-wavelength radials, given for comparison.

It's important to note (see **fig. 9**) that hemispherical coverage is achieved, allowing the antenna to be used for both local and long range communications. As a result of its magnetic properties, a loop antenna produces significant radiated energy at low elevation

angles. This also confirms that there is very little ground loss for this antenna.

On-the-air tests, in comparison with other antennas, have confirmed the performance of the convoluted loop and verified the performance indicated by the patterns derived from MININEC3. Measurements on the antenna also confirm the accuracy of the equations. A sample run of the computer program is shown in **fig. 11**, to assist those who want to develop a convoluted loop antenna for a particular application. **Figure 12** presents a set of data run from the program.

The convoluted loop is a result of efforts to design a high-performance antenna requiring very little space. I hope others will modify this design (perhaps by putting a "twist" to the conductor) and achieve an antenna design that's truly nondirectional.

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ELMER's NOTEBOOK

Tom McMullen, W1SL

Voltage-variable capacitors

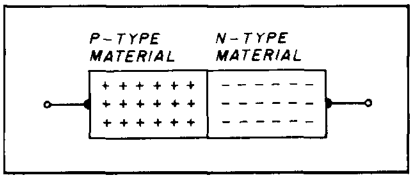
I'm planning a column for the near future about oscillators and what makes them work. For now I'd like to talk about one of the components used in many oscillators — a diode that acts like a variable capacitor. I thought a review of how this diode works would be useful. You may think that because it doesn't look like a capacitor, it can't act like one. But some variable capacitors can have an appearance completely different from those of earlier days and still pass the test.

For high-power use (in the power-amplifier stages of a transmitter or in an antenna-matching network, for example) the mechanically variable capacitor with its tolerance of high voltages is still the only way to go. For receiver RF amplifier stages or frequency-synthesized variable-frequency oscillators (VFOs), a little speck of plastic and metal will perform the same function as a mechanically variable capacitor — in far less space. They have other advantages as well.

How do they do that?

To understand how the process works, a physics lesson is in order. In earlier discussions of semiconductor devices like bipolar and field-effect transistors, I spoke of how they are made up of two types of material: P-type (with a scarcity of electrons) and N-type (with a surplus of electrons). These two kinds of materials can be put together to form a diode, as shown in **fig. 1**. Conductive leads

FIGURE 1



P-type semiconductor material and N-type semiconductor material are placed together to form a diode. The material can be either germanium or silicon.

are attached to each end to allow current flow from external sources and devices. The barrier or junction between the two materials is very thin, and a small voltage (0.6 volts for silicone devices) overcomes its resistance and permits current flow. Germanium devices require less voltage (typically 0.2 volts) to allow conduction.

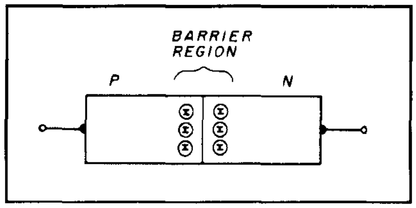
It's necessary to apply forward bias to the diode to obtain conduction when you want to rectify some AC, isolate a DC source, or whatever. But things start to get interesting when you apply reverse bias to the diode.

To go back to the basic physics of the device for a moment, it's the junction (or barrier) region that's important. When the two types of semiconductor material are attached to each other, a small number of electrons from the N-side cross the barrier and fill some of the vacancies on the P-side. These vacancies are often called "holes," but they're not really holes — they're atoms that have one less electron compared with the other atoms around them. These are the "impurity" atoms that were mixed in with the basic silicon or germanium when the alloy was formed.

Over on the N-side of the barrier, some impurity atoms have an extra electron compared with those surrounding it — hence the "surplus" of electrons. When enough surplus electrons from the N-side "cross over the fence" to fill the vacancies on the P-side, the semiconductor material close to the fence on both sides has neither surplus tenants nor vacancies. (This kind of material is called type "I," for intrinsic, which is another way of saying it reverted to its original number of electrons before the impurities were mixed in.)

Take a look at **fig. 2** and see what you have now. There are two types of

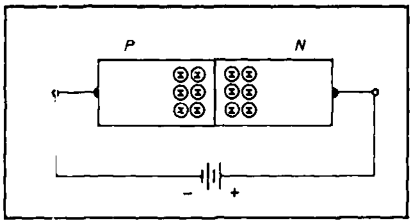
FIGURE 2



Some electrons migrate from the N-material over to the P side, creating a barrier region with neither surplus electrons nor vacancies for them. In this state, the barrier region is an effective insulator.

semiconductor material, with an insulator layer in between. It's beginning to look like a basic capacitor — two conductors separated by an insulator or dielectric. Now, let's see if acts like one.

FIGURE 3



When a voltage is applied to the diode, more electrons are available to fill more vacancies, causing the barrier region to grow. This effectively changes the amount of insulation (dielectric) between the two conductors.

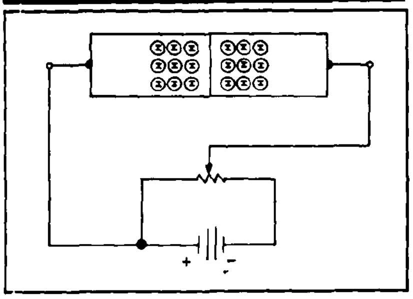
Add some voltage and...

When an external source of electrons is connected to the junction (from a battery or power supply, for instance) the resulting pressure (also known as voltage) lets more electrons cross the barrier and fill some vacancies, as shown in **fig. 3.** To put it another way, the crowd along the fence is getting bigger. This is the same as putting a bigger insulator (dielectric) between the two plates of the capacitor. If this were an air-dielectric capacitor, you'd get the same effect by moving the plates farther apart. So now you have a varible-dielectric capacitor. Is this thing beginning to act like a capacitor? Sounds like it!

Can we control it?

Because this capacitor changes its dielectric in response to applied voltage, and since a change in dielectric equates to a change in capacitance, it is a variable capacitor. From here it should be easy to control the capacitance, as shown in **fig. 4.**

FIGURE 4

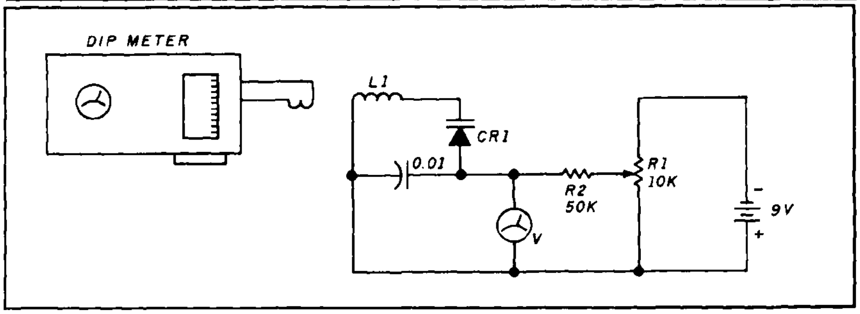


A variable voltage applied to the diode will cause the barrier region, and thus the capacitance, to change in response to the voltage.

To demonstrate the principle, connect a potentiometer across a power supply (a 9-volt battery in this case). You'll need a means of detecting the capacitance change in order to get proof that it works. My ancient capacitance meter doesn't do well with values below 50 pF, so I came up with the scheme in **fig. 5.** L1 and CR1 comprise a tuned circuit that you check with a grid-dip meter. (My meter uses a vacuum tube, so it's still a "grid" dipper. A transistor or FET dipper will work equally well). L1 is ten turns of no. 22 enameled wire close wound on a 1/4-inch form, and CR1 is the diode being tested. R1 is a variable resistor that controls the voltage applied to the diode, and R2 is a current-limiting device — in case something should short. C1 is a large-value bypass capacitor, which completes the RF path in the tuned circuit and isolates the meter from the circuit.

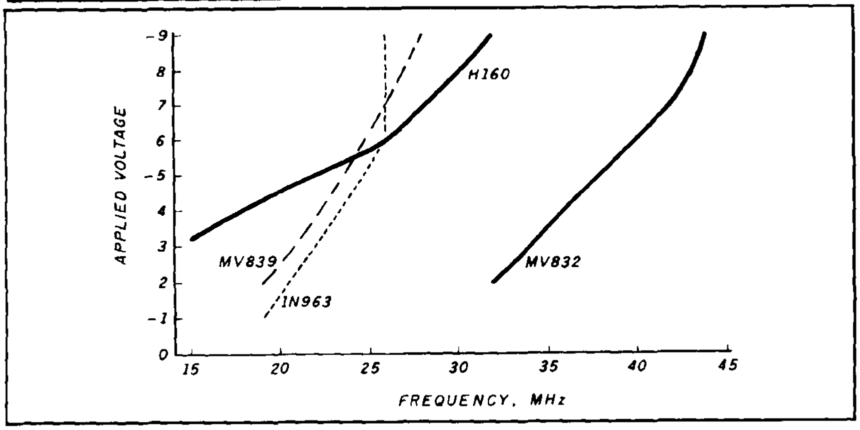
I placed the dip meter as far away as I could from the tuned circuit while still getting an indication on its meter. This prevents overloading the circuit with RF, which could cause CR1 to act like a regular diode instead of a variable-capacitance diode. Then I measured the voltage applied to the diode and checked the frequency. I changed the voltage and took another frequency reading. **Figure 6** is a graph of my results. The first diode I tested was a prototype designed for use in AM broadcast band circuits, marked

FIGURE 5



If you don't have a capacitance meter capable of reading values down to 10 pF or less, you can test the principle with this setup. Components are explained in the text.

FIGURE 6



A plot of voltage versus frequency shows the results. A plot for a diode (1N963) not designed for use as a VVC (voltage-variable capacitor) is also shown. Its limited range is shown by the "knee" at −6 volts.

H160. I also tried two other types designed for voltage-variable capacitance use, the MV832 and MV839.

According to theory, almost any diode will act like a variable-capacitance diode to some degree, so I grabbed a 1N963 from my junkbox and wired it into the circuit to see what would happen. The results are also shown in **fig. 6**.

It became quite evident during this test that it's important to use a diode designed for the job. The 1N963 has a lower Q than the other diodes. I knew this because the "dips" at resonance were very shallow and broad in frequency. The MV832 also showed the same behavior, but not as severely as the 1N963. The MV832 has a smaller capacitance change than the others, as shown by its position on the graph. It should work well in the VHF region. The other diodes produced dips at resonance that were quite sharp, as expected of high-Q devices.

It appears that theory has triumphed again. You have a variable capacitor that can be controlled by a potentiometer and voltage source. This opens up a lot of possibilities, and eliminates those fussy shaft couplers that were always so hard to align with the dial drive on the front panel of your VFO. All the normal precautions about shielding, temperature compensation, anti-vibration protection, and the like still apply, however. A VFO circuit must be mechanically stable, no matter what type of capacitor you use. All diodes change characteristics with temperature; these will too, to some extent. It's not critical in many circuits, but this trait will be noticeable in a VFO.

And that's what makes a voltage-variable capacitor (sometimes known as a varicap) work. When my notebook item about oscillators appears in a later issue, you'll understand what that funny-looking diode is doing in the middle of things.

Article L HAM RADIO

NEW products

New for remote antenna switching

ComTek announces the new RCB-5 Remote Control Box — a five-position coaxial switch for remote antenna switching from one feedline.

The RCB-5's inside console control box selects from one to five antennas at once; the weatherproof outside switchbox contains five high-powered DPDT relays with gold-plated contacts. The RCB-5 can be used as a standard five-position remote control coaxial switchbox or to control stacked arrays. Optional wideband Toroidal Impedence Transformers (TIT-2 or TIT-3) for 50 to 100 ohms or 50 to 150 ohms are available for stacking two or three Yagis, respectively. All relays have 5 kW-rated gold-plated contacts. VSWR is below 1.05:1 up to 144 MHz. The outside switchbox uses 18-gauge steel with a zincate coating, a gold-chromate rustproof finish, and is dip-painted black. The inside console control box has a scratchproof Lexan™ front panel template. LEDs have diffusion covers. The switching knob has positive action with 15-degree detent positions.

The RCB-5 comes with 250 QSL cards, and is priced at $139.95 plus $12 shipping and handling. (Add 10 percent outside the U.S.) TIT-2 or TIT-3 comes in a weatherproof box with SO-239 IN and OUT for $19.95.

For further information contact ComTek, PO Box 202, Hopkinton, Massachusetts 01748.

Circle #305 on Reader Service Card.

Compact Amplified Speaker

Naval Electronics, Inc. has introduced the HTS-1 Amplified Speaker with features for use with handheld radios. The HTS-1 is compact, with a 3.5-inch speaker and 10-dB internal amplifier.

The HTS-1 is powered from internal batteries, or any external voltage from 6 to 15 Vdc through a DC jack. It has a built-in NiCd battery charger and an automatic shut-off that kills power to the amplifier when there's no audio input (receiver squelched). When switched off manually, the amplifier is bypassed and the input jack has a direct connection to the speaker.

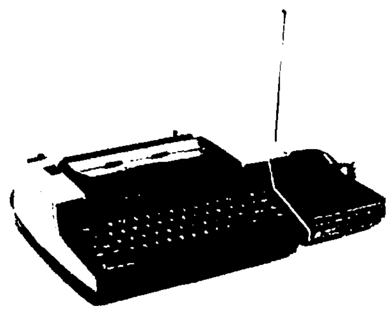
The HTS-1 has a tilted base for desk mounting. A special mobile harness is available for mounting the unit on the inside of a car door. A 5-foot cable with mini-plugs and a stereo-to-mono converter is included. A free stereo cable is available if you order two units for use with a personal stereo system. The cost is $29.95.

For further information contact Naval Electronics, Inc., 5417 Jetview Circle, Tampa, Florida 33634.

Circle #306 on Reader Service Card.

Printers communicate by packet radio

QWINT DATA, Inc. has announced a new packet radio modem option. It's packaged as an internal module with the QWINT terminal. The RDM1200 lets you send and receive written messages over radio links.



Characters are sent and received in the form of audio frequency tones. To provide error-free messages over radio, the modem includes a high-speed 7.37-MHz microprocessor, with these features:

- Synchronous HDLC protocol
- Automatic error detection and correction
- Multi-user networks
- Repeater capability
- Compatibility with HF, VHF, and UHF

The QWINT terminal may be interfaced with most voice radio transceivers. A jack and cable are provided. The radio modem connects to the microphone and speaker jacks of the voice radio. It also provides a digital output for controlling PTT circuitry, for switching into transmit mode under control of the packet radio protocol.

For more information contact QWINT DATA, Inc., 3455 Commercial Avenue, Northbrook, Illinois 60062.

Circle #307 on Reader Service Card.

ACB-4 phased array switchbox

ComTek introduces the ACB-4 phased array switchbox with controller. It allows gain and directivity from a vertical array by dividing power and phase among 2 or 4-element arrays. You supply the antennas and cables.

The ACB-4 has two boxes. The outside switchbox, installed near the antenna array, contains the 90-degree quadrature hybrid, 180-degree phase reversal transformer (both in toroidal form), and relay switching matrix. Four feedlines are attached to the antenna elements for a "4-Square" array; two are used for a 2-element array. Three-conductor control cable and feedline run back to the shack. Gain for the 4-square is about 5.8 dB with F/B typically 15 to 25 dB, depending on angle of arrival. Metal cabinets are 18-gauge steel, with anti-rust zincate and gold cromate finish, dip painted black. Relays use 5-k gold-plated contacts. The inside console control box has a scratchproof Lexan™ front panel template. The beam direction knob has positive click positions and no end stop, for continuous turning in any direction. The ACB-4 comes with complete instructions for installing ground-mounted verticals, ground-plane type verticals, or half-wave verticals with the unit. The price is $295, plus $12 shipping and handling. (Add 10 percent outside the U.S.). Contact ComTek, PO Box 202, Hopkinton, Massachusetts 01748.

Circle #309 on Reader Service Card.

GP21X Ginpole Kit

IIX Equipment, Ltd. offers the new GP21X Ginpole Kit for stamped open leg-type towers. Clamps adjust to fit the tapering tower sections and can be spaced any distance apart. A standard IIX pulley is furnished; the pipe is customer supplied. The price of the kit is $199.50. Immediate shipping is available.

For more information contact IIX Equipment, Ltd., PO Box 9, Oak Lawn, Illinois.

Circle #308 on Reader Service Card.

DX FORECASTER

Garth Stonehocker, KØRYW

Spring thunderstorm noise

Received noise sometimes spoils the best DX openings. There are many types of noise. The Russian woodpecker or the ham rig down the street are two examples of radio emitters, which can cause interference. Atmospheric, or thunderstorm, noise is more common. Like the DX signal, these noises are often propagated by the ionosphere. Other noise may come from a local factory or a badly maintained power line. Of all of these, strong local atmospheric noise is perhaps the most disagreeable at this time of year. Here's how it happens.

Spring storms occur in the Northern Hemisphere in March and April. Fronts of warm and cold air generate the first major thunderstorms of the year, with fast-moving cold fronts producing particularly potent thunderstorms. As a storm front approaches your area, you'll begin to hear a significant increase in the noise level. You'll start to notice this increase at a one-hop distance (about 600 to 1200 miles) when the storm front is west of your location. You can reduce the received noise a few dB by using a directional antenna like a rotating Yagi or a phased vertical array. Determine the noise direction and work DX in the opposite orientation, or do your best to null it out using a directional tradeoff between signal and noise strengths. Antennas with a low take-off angle (TOA) at the operating frequency are best because this noise normally arrives at angles greater than 30 degrees.

As the front gets closer, the noise level usually decreases until it's within a groundwave's distance (about 50 miles). Now you'll hear loud individual discharges. A horizontally polarized antenna is the best radiator to use to lower the noise as much as possible. As the storm approaches, its sounds become part of the "local noise." As it moves away its noise decreases, then increases again as the front reaches the one-hop distance point a day or so later. The directional low TOA antenna is helpful once again.

Cold fronts usually travel about 40 miles per hour, so it could take 15 to 30 hours to reach one-hop distance — averaging almost a day's frontal travel time before coming to (westerly) and after leaving (easterly) your station. If you watch the TV weather news daily, you can track the storm and note how its noise affects your operations. As the storm comes into the one-day-before position, there's a corresponding increase in noise. When it passes over your ham shack the next day, it will cause intense static crashes. As you watch the storm approach the day-after position, you'll notice some lingering noise before all's quiet again. It should remain quiet until the next storm comes your way. When looking for rare DX, you can save time by tracking storms. This will help you pinpoint when and where the most favorable listening conditions are likely to occur.

Last-minute forecast

The first and last weeks of the month should be times of high solar flux, resulting in higher MUF than the rest of the month. There's also a probability of solar flares, if the rise or fall of flux is over ten units per day — an April trait. The high MUFs will enhance DX conditions to the southern countries. The openings may be transequatorial DX openings toward late evenings (2200 local time), and during geomagnetic-ionospheric disturbances expected near the 5th through the 8th, the 16th, and the 26th. The lower night or daytime short-skip bands should be best the second and third weeks during times of lower solar flux, with its lower signal absorption. MUFs will come down nearer these bands and produce strong signals. During the disturbed days (and particularly nights), signals may be weak and variable (QSB) but from interesting DX countries. This is also an April trait.

The perigee of the moon's orbit (for moonbounce DX) is on the 5th, with the moon showing full phase on the 21st. There will be a short meteor shower (the Lyrid) on April 20th to the 22nd, with a rate of five per hour — hardly much help for meteor scatter DX. But a bigger shower (the Aquarid) starts before the end of April, peaks on May 5th, and ends in mid-May. Its rate should be 10 to 30 per hour.

Band-by-band summary

Ten, 12, 15, and 17 meters, the day-only DX bands, will be open midday to early evening almost every day to southern areas of the world. The openings on the higher of these bands will be shorter (if they occur at all), closer to local noon, and will provide a possibility of transequatorial openings.

APRIL

WESTERN USA

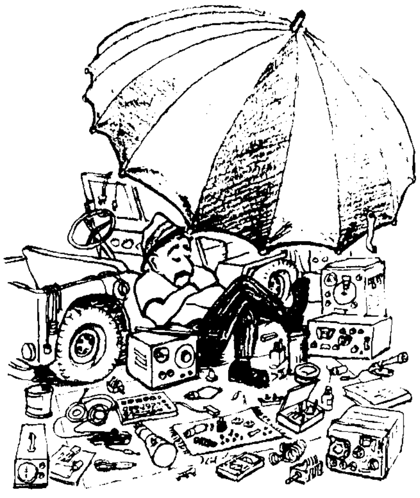
GMT	PDT	N	NE	E	SE	S	SW	W	NW
0000	5:00	12	30	15	10	10	10	10	10
0100	6:00	12	30	15	10	10	10	10	10
0200	7:00	12	30	20	12*	12	10	10	10
0300	8:00	15	30	20	12	12	10	10	12
0400	9:00	15	20	20	12	15	10	10	15
0500	10:00	20	20	20*	15*	20	10	10	15
0600	11:00	20	20	15	15	20	10	10	20
0700	12:00	20	20	15	15	20	12	12	20
0800	1:00	20	30	15	20	20	12	12	20
0900	2:00	30	30	20	20	20	15	15	20
1000	3:00	30	30	20	20	20	15	15	20
1100	4:00	30	20	15	20	30	15	15	20
1200	5:00	20	15	12	20	30	20	15	30
1300	6:00	20	12	10	15	30	20	20	30
1400	7:00	20	12	10	12	30	20	20	20
1500	8:00	20	10	10	12	30	20	20	20
1600	9:00	20	10	10	10	20	20	20	20
1700	10:00	20	12	10	10	15	15	20	30
1800	11:00	30	12	10	10	12	12	20	20
1900	12:00	30	15	10	10	12*	12	15	15
2000	1:00	30	15	10	10	10	10	12	15
2100	2:00	20	15	12	10	10	10	10	12
2200	3:00	20	20	12	10	10	10	10	12
2300	4:00	15	20	15	10	10	10	10	10
		SIA AR EAST	JROPE	. AFRICA	. AMERICA	NTARCTICA	EW ZEALAND	CEANIA USTRALIA	APAN

MID USA

MDT	N	NE	E	SE	S	SW	W	NW	CDT
6:00	15	20	15	10	10	10	10	10	7:00
7:00	15*	20	15	10	12	10	10	12	8:00
8:00	12	30	20	12	12	10	10	15	9:00
9:00	15	30	20	12	15	10	10	15	10:00
10:00	20	30	20	12	20	10	12	15	11:00
11:00	20	20	20	15	20	12	12	20	12:00
12:00	20	20	15	15	20	12	15	20	1:00
1:00	20	20	15	15	20	12	15	20	2:00
2:00	30	30	20	20	20	15	15	20	3:00
3:00	30	30	20	20	20	15	15	20	4:00
4:00	30	30	15	20	20	15	15	30	5:00
5:00	15	20	12	20	30	20	20	30	6:00
6:00	15	20	10	15	30	20	20	30	7:00
7:00	15	15	10	12	30	20	15	20	8:00
8:00	20	15	10	12	30	20	15	20	9:00
9:00	20	12	10	12*	30	20	20	20	10:00
10:00	20	12	10	10	15	15	20	30	11:00
11:00	20	12	10	10	15	12	20	30	12:00
12:00	20	12	10	10	12	12	20	30	1:00
1:00	30	15	10	10	10	12	12	15	2:00
2:00	30	15	12	10	10	10	10	15	3:00
3:00	30	20	12	10	10	10	10	12	4:00
4:00	20	20	15	10	10	10	10	12	5:00
5:00	20	20	15	10	10	10	10	10	6:00
	SIA AR EAST	UROPE	. AFRICA	. AMERICA	NTARCTICA	IEW ZEALAND	CEANIA USTRALIA	APAN	

EASTERN USA

EDT	N	NE	E	SE	S	SW	W	NW
8:00	15	20	15	10	12	10	10	12
9:00	20	20	15	10	12	10	10	15
10:00	20	30	20	12	15	10	10	15
11:00	20	30	20	12	15	10	10	20
12:00	20	30	20	15	20	12	12	20
1:00	30	30	20	15	20	12	12	20
2:00	30	30	20	15	20	15	15	20
3:00	30	30	20	20	20	15	15	30
4:00	20	20	20	20	20	15	15	30
5:00	20	20	15	20	30	15	15	30
6:00	15	15	12	20	30	20	20	20
7:00	15	15	10	15	30	20	20	20
8:00	15*	15	10	12	30	20*	15	20
9:00	15	15	10	12	30	20	15	20
10:00	15	12	10	12	30	20	20	20
11:00	20	12	10	10	15	20	20	20
12:00	20	15	10	10	15	20	20	30
1:00	20	15	10	10	12	15	20	30
2:00	20	15	10	10	12	12	20	20
3:00	30	15	10	10	10	12	12	15
4:00	30	20	10	10	10	10	10	12
5:00	30	20	10	10	10	10	10	12
6:00	20	20	12	10	10	10	10	10
7:00	20	20	12	10	10	10	10	10
	SIA AR EAST	UROPE	S. AFRICA	CARIBBEAN S. AMERICA	ANTARCTICA	NEW ZEALAND	OCEANIA AUSTRALIA	JAPAN



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BEGINNER'S RADIO CLEARINGHOUSE. On a space available basis, we are going to offer you, OUR SUBSCRIBER, free of charge, a chance to find a home for your used equipment with a new Ham. Please send us a short description of what you want to sell along with price, name, address and phone number. We'll run it once in a special section of the classified ads under the heading of BEGINNER'S RADIO CLEARINGHOUSE. Please limit your ad to 20 words or less.

NYE VIKING MB-II-01 *Antenna Tuner w/SWR/Wattmeter*, $135. B&W 6-pos CS-6G coax switch, $20. Duane Heise, AA6EE, 16832 Whirlwind, Ramona, CA 92065. (619) 789-3674.

NATIONAL Radio Manual and NCL-2000 factory parts lists. SASE. Max Fuchs, 11 Plymouth Lane, Swampscott, MA 01907.

ELECTRONIC KITS & ASSEMBLIES. For our latest catalog send SASE (45 cents) to: A & A ENGINEERING, 2521 W. LaPalma, #K, Anaheim, CA 92801.

IBM-PC SOFTWARE FOR PK-232. New CompRtty II/PK is the complete communications program for the PK-232/HK-232. Uses host mode of PK-232 for complete control. Text entry via built-in screen editor! Adjustable split screen display, including optional Triple Split ™ in Packet mode. Instant mode/speed change. Hardcopy, diskcopy, break-in buffer, select calling, text file transfer, customizable full screen logging, 24 programmable 1000 character messages, mailbox facility. Ideal for MARS and traffic handling. Requires 256k PC compatible. $65. Non-PK-232 version still available. Send call letters (including MARS) with order. David A. Rice, KC2HO, 144 N. Putt Corners Rd, New Paltz, NY 12561.

COMMODORE/AMIGA CHIPS (eg. 6510-$12.55, 6526-$13.50, 6567-$19.95, 6581-$14.85, 82S100-$15.75, 901 ROM Series-$12.50), **PARTS, DIAGNOSTICS, HARD TO FIND ITEMS.** Authorized service center. Fast **REPAIRS**, low cost *(eg. C64-$49.95 plus UPS). Heavy duty power supplies for the* C64-$27.95 plus UPS. Kasara Microsystems (Division of QEP), Route 9W/Kay Fries Drive, Stony Point, NY 10980, 1-800-248-2983 (outside NY) or 914-942-2252.

THE NATIONAL HAM SHOPPER. A bi-monthly buy, sell, trade publication (starting in April). Ads are quickly answered and published for fast results. $12/per year. $22/per 2-year subscription rate. Send: PO Box 10738, Elmwood, CT 06110.

R-290A Receiver Parts: Info SASE. CPRC-26 military Manpack Radio, 6 meter FM, with antenna, crystal, handset: $22.50, $42.50/pair. CPRC-26 Radio-only: $9.50. Add $4.50/piece shipping, $9 maximum. Baylronics, Box 591, Sandusky, OH 44870.

VHF MOBILE REPEATER, control ham station with HT, w/manual $75. Precision E-200-C RF signal generator 90kc-240mc $50. Heath ET-3100 semiconductor course with lab trainer $80. Other ham test equipment. K6KZT, 2255 Alexander, Los Osos, CA 93402. (805) 528-3181.

COMMUNICATIONS BATTERIES: Clone Packs! Ready-for-use. ICOM: BP5 $44.95, BP-3S 2X cap. BP3 "Wall Chargeable" $43.95, BP-7S 2X BP7 (5W only) or BP8S (BP8 + 50%) (Base Chg-only) $67.95, YAESU: FNB2 $22.95, FNB10S (10 + 60%) $49.95, SANTEC 142 $23.95. * Repair Inserts * ICOM: BP2 $18.95, BP3 $16.95, P5 $24.95, BP7/BP8 $29.95, KENWOOD: PB21 $13.95, PB24 $21.95, PB25/26 $25.95, YAESU: FNB4/4A $33.95, TEMPO: S1,2,4,5,15/450 $23.95, AZDEN: 300 $21.95. * E.P. Porta-Pac & Chgr 12V/5Ahr $44.95 * * Rebuilding * Send pack—*free estimate*. * Antennas * Ducks/BNC $8.95, 2mtr 5/8-Tel/BNC $18.95. SASE Catalog. PA + 6%. $3 Shipping/order. VISA-M/C + $2. (814) 623-7000. CUNARD ASSOCIATES, Dept H, RD 6, Box 104, Bedford, PA 15522.

DIGITAL AUTOMATIC DISPLAYS. Any Radio. Be specific. GRAND SYSTEMS, POB 2171, Blaine WA 98230.

FOR SALE: Amateur Radio collection. Receivers, transmitters, tubes, magazines, books. Misc. SASE for list. K4UJZ, 608 West Thompson Lane, Murfreesboro, TN 37129. (615) 893-5344.

SELL ITT Mackay digitally synthesized communications receiver model 3031A. Coverage 0.015-30 MHz, frequency selection within 5 Hz. Operated for less than 200 hours. Price $2800 or highest bid plus shipment. Weighs 19 lbs. Contact John Ekwall, Box 6014, S-60006. Norrkoping, Sweden.

ENGINEER WANTED. With Ham experience to develop Ham products. Exciting proposition for the right person. Box 498, Greenville, NH 03048.

MANY THANKS and Happy New Year to those who have helped me in acquiring old bugs. Still looking. WB4EDB, Smiley White, PO Box 5150, Fredericksburg, VA 22403. (703) 373-0996 Collect.

RECEIVER LAFAYETTE HE-10, *general coverage extra clean* $85. Swan FM-2X 2 meter mobile $90. Regency HR-2A 2 meter $85. K6KZT, 2255 Alexander, Los Osos, CA 93402. (805) 528-3181.

ANYONE INTERESTED in starting a firefighters net on HF send ideas or contact KA4TLC, Ricky Martin, Rt 1, Box 199-J, Hope Mills, NC 28348.

WANTED: We need Tektronix plug in, type 1L10, 1L20, 1L30, spectrum analysis for oscilloscope Tektronix type 547 and photocopy technical manual plug in 1S2 Tek. Angel Alvarez, EA1NN, San Anton 18-8-A 26002 Logrono, Spain

UHF PARTS. GaAs Fets, mmics, chip caps, feedthrus, teflon pcb, high Q trimmers. Moonbounce quality preamps. Electronic sequencer boards. Send SASE for complete list or call (313) 753-4581 evenings. MICROWAVE COMPONENTS, PO Box 1697, Taylor, MI 48180.

COMMODORE-128 PROGRAM available to track the Amateur Satellites. Uses Keperlian data supplied by NASA free. Tracks up to 8 satellites simultaneously. Program also supports printing schedules and predictions for satellites. Use it to track MIR and talk to the Cosmonauts. SATRAK128, $26.50 includes shipping. Other information on this or other programs for the C128, requires a business size SASE. Reid Brislor, WA4UPD, PO Box 0773, Melbourne, Florida 32936-0773.

WANT: 32S3 xmtr, 250TL and 304TL tubes. KF6WM, 45300 Royal, King City, CA 93930.

DXERS—CUSTOMIZED PRINTOUT of antenna headings calculated for your location. List includes over 650 worldwide locations. Send Lat/Long coordinates, name, callsign, check for $12.95 U.S. Brian Henderson, VE6ZS, 23 Deermoss Pl SE, Calgary, Alberta, Canada T2J 6P5. (403) 278-2084.

WANTED: Operation/service manuals for Galaxy V transceiver. Joe Williams, KJ6OF, 38665 11th Street E., #2, Palmdale, CA 93550. (805) 947-1641 eves.

HANDICAPPED NOVICE needs HF equipment donated—anything please. KA3OUE, (412) 531-7443 anytime.

OFFICIAL MILITARY-TYPE ID TAGS. ("Dog Tags")!! Customized with your Call Letters, etc. 5 seventeen space lines. 20" nickel plated chain included. $4.29 postpaid. JPW ENTERPRISES, PO Box 353, Logan, Utah 84321

MAGAZINES WANTED: "Microwave Systems News" (MSN), "RF Design", "PCIM (Power Conversion & Intelligent Motion)" and "QEX" (1980-present). Call collect 519-742-4594 (Ontario) after 6 PM Eastern time.

IMRA International Mission Radio Association helps missionaries. Equipment loaned. Weekday net, 14.280 MHz, 1-3 PM Eastern. Nine hundred Amateurs in 40 countries. Rev. Thomas Sable, S.J., University of Scranton, Scranton, PA 18510.

BACK ISSUES OF HAM RADIO. Have most issues from 1969 to 1974. Mint condition. $3.00 for single issues. WN0G, 319-377-3563.

HAM TRADER YELLOW SHEETS. In our 27th year. Buy, swap, sell ham radio gear. Published twice a month. Ads quickly circulate—no long wait for results. Send No. 10 SASE for sample copy. $13 for one year (24 issues). PO Box 2057, Glen Ellyn, IL 60138-2057 or PO Box 15142, Dept HR, Seattle, WA 98115.

VHF-UHF-SHF. Large SASE. West Coast VHFer, POB 685, Holbrook, AZ 86025.

CHASSIS & CABINET KITS. SASE. K3IWK, 5120 Harmony Grove Rd, Dover, PA 17315.

ANALOG AND RF CONSULTING for the San Francisco Bay area. Commercial and military circuits and systems. James Long, Ph.D., N6YB (408) 733-8329.

RTTY JOURNAL—Now in our 36th year. Read about RTTY, AMTOR, PACKET, MSO'S, RTTY CONTESTING, RTTY DX and much more. Year's subscription to RTTY JOURNAL $10.00, foreign slightly higher. Order from: RTTY JOURNAL, 9085 La Casita Ave., Fountain Valley, CA 92708.

RUBBER STAMPS: 3 lines $5.00 PPD. Send check or MO to G.L. Pierce, 5521 Birkdale Way, San Diego, CA 92117. SASE brings information.

ELECTRON TUBES: Receiving, transmitting, microwave... all types available. Large stock. Next day delivery, most cases. DAILY ELECTRONICS, PO Box 5029, Compton, CA 90224. (213) 774-1255.

"HAMLOG" COMPUTER PROGRAM. Full features, 17 modules. Auto-logs, 7-band WAS/DXCC. Apple $19.95. IBM, CP/M, KAYPRO, Tandy, C128 $24.95. **HR**-KA1AWH, POB 2015, Peabody, MA 01960.

WANTED: ARC-5 and SCR-274 equipment, parts and accessories, any condition. Ken, WB9OZR, 362 Echo Valley, Kinnelon, NJ 07405. (201) 492-9319.

WANTED: Ham equipment and other property. The Radio Club of Junior High School 22 NYC, Inc. is a nonprofit organization, granted 501(C) (3) status by the IRS, incorporated with the goal of using the theme of Ham Radio to further and enhance the education of young people. Your property donation or *financial support would be greatly appreciated and* acknowledged with a receipt for your tax deductible contribution. In Dayton, meet the crew from 22 and relax at our flea market tables, check in on 144.30 simplex. Please write us at: PO Box 1052, New York, NY 10002. Or call our round the clock hotline: (516) 674-4072. Thank you!

HALLICRAFTERS S-40 receiver (1946), fair condition, with service manual, $40 plus shipping. Include SASE. Nate Williams, W9GXR, 6915 Prairie Drive, Middleton, WI 53562.

HAM PROGRAMS and other "shareware" for IBM/compatibles. Large SASE for catalog. JK&S, POB 50521, Indianapolis, IN 46250-05221.

CUSTOM MADE EMBROIDERED PATCHES. Any size, shape, colors. Five patch minimum. Free sample, prices and ordering information. HEIN SPECIALTIES, Inc., Dept 301, 4202 N. Drake, Chicago, IL 60618.

WANTED: Drake Linear Amp Model MN4439- 1000W (2000 PEP), 1.8-30 MHz. Call Bruno Molino, VE2FLB, 26 Rue Des Anciens, Gatineau, Quebec J8T 3T2. (819) 561-3689.

RECONDITIONED TEST EQUIPMENT $1.25 for catalog. Walter, 2697 Nickel, San Pablo, CA 94806.

SCHOLARSHIP. The Dayton Amateur Radio Association is now accepting applications for its 1989 Scholarship Program. The program is open to any licensed Amateur graduating from high school in 1989. For information and application forms write Scholarship Committee, 317 Ernst Avenue, Dayton, OH 45405.

COMING EVENTS

Activities — "Places to go . . ."

SPECIAL REQUEST TO ALL AMATEUR RADIO PUBLICITY COORDINATORS: PLEASE INDICATE IN YOUR ANNOUNCEMENTS WHETHER OR NOT YOUR HAMFEST LOCATION, CLASSES, EXAMS, MEETINGS, FLEA MARKETS, ETC, ARE WHEELCHAIR ACCESSIBLE. THIS INFORMATION WOULD BE GREATLY APPRECIATED BY OUR BROTHER/SISTER HAMS WITH LIMITED PHYSICAL ABILITY.

Twenty, 30, and 40 meters are both day and night bands. Twenty meters is the maximum usable band for DX in the northern directions these days during the daytime. It then teams up with 30 meters to extend this coverage into the evenings. Forty meters becomes the main over-the-pole DX daytime band, with some hours covered by 30 meters.

Eighty and 160 meters, the night-only DX bands, will exhibit short-skip propagation during daylight hours, then lengthen for DX at dusk. These bands follow the darkness path, opening to the east just before your sunset, swinging more to the north-south near midnight, and ending up in the Pacific areas during the hour or so before dawn.

Article M **HAM RADIO**

MICHIGAN: April 1. S.T.A.R.S. Amateur Radio Association's annual Swap & Shop, Grandville High school, Grandville, 8 AM to 2 PM. Tickets $3/advance; $3.50/door. Tables—1st free, second $3.00. All indoors. Plenty of parking. Talk in on 145.270 K8XL/R. For information S.T.A.R.S., 1714 Havana SW, Wyoming, MI 49509. (616) 243-17509.

MARYLAND: April 1-2. The Baltimore Amateur Radio Club (BARC) will present the 1989 Greater Baltimore Hamboree and Computerfest, Maryland State Fairgrounds Exhibition Complex at Timonium. Gates open 8 AM. Admission $5 for both days. Children under 12 free. Large indoor dealer area. Indoor/outdoor flea market. For more information or reservations contact GBH&C, PO Box 95, Timonium, MD 21093-0095. Call (301) HAM-FEST 24 hr.

OHIO: April 2. The 11th annual Lake County Hamfest, Madison High School, Burns and Middle Ridge Roads, Madison. 8 AM to 3 PM. All indoor flea market, exhibits, programs, prizes, VE exams. Admission $4/door; $3/advance. 6' tables $5, 8' tables $6.50. Talk in on 147.21/81, 222.90/224.5. Contact Roxanne, 7803 Skylineview Drive, Mentor, OH 44060. Please SASE. (216) 953-9784.

COLORADO: April 2. The Longmont ARC is sponsoring a combined Hamfest and Computer Swap, Boulder County Fairgrounds, Longmont. 8 AM to 3 PM. For information Bob Dornan, WA2EKU, 1106 Fordham St, Longmont, CO 80501. (303) 651-3613 or Ken Parker, W0ONF, 1221 Aspen St, Longmont, CO 80501. (303) 772-4719.

ONTARIO: April 8. The 8th annual Durham Region Amateur Radio and Computer Flea Market. 9 to 2. Pickering High School, Church Street North, Pickering Village, Ajax. Sponsored by the South Pickering and North Shore ARC's. Admission $4. Vendors tables $7 plus admission by March 15. $10 plus admission thereafter. Talk in on 147.975 and 147.720. Reservations payable to South Pickering ARC, PO Box 53, Pickering, Ontario L1V 2R2. For information Ron Brown, VE3WZ (416) 839-3711. Mike Sherba, VE3DKW (416) 723-7674. Steve Bezuk, VE3MCZ (416) 831-0312.

MASSACHUSETTS: April 16. Tailgate electronics, computer and Amateur Radio Flea Market, Albany and Main Street, Cambridge. 9 AM to 4 PM. Sponsored by the MIT Radio Society and the MIT Electronics Research Society. Admission $1.50. Free off street parking for 1000 buyers. Sellers $6/space; $5/advance. Includes 1 admission. Setup 7 AM. For reservations before April 1 (617) 253 3776. W1GSL, PO Box 82 MIT Br, Cambridge, MA 02139. Talk in on 146.52 and 449.725/444.725—pi 2A—W1XM/R.

OKLAHOMA: April 15. The Lawton-Fort Sill ARC will hold their 41st annual Hamfest, County Fairgrounds, 8 AM to 5 PM No pre-registration necessary except for table space. Talk in on 147.39/99. For information Claude R. Matchette, 3411 NW Atlanta Avenue, Lawton, OK 73505. (405) 357-5870.

WEST VIRGINIA: April 15. The 5th annual Charleston Area Hamfest and Computer Show sponsored by the Tri-Counties Ham Club and the Kanawha ARC. 9 AM to 4 PM, Charleston Civic Center, Charleston, WV. Admission $5. Tables $6 each. A/C power $12. Walk-in VE exams. For dealer/flea market information write PO Box 1694, Charleston, WV 25326 or phone Bill Hutner, K8BS (304) 744-2650 or Lovell Webb (304) 342-7247. For other information write PO Box 9076, So. Charleston, WV 25309 or phone Doug Sweeney (304) 766-6655.

MINNESOTA: April 15. The Lake Region Amateur Radio Club's 2nd annual Hamfest, Otter Tail County Fairgrounds—Hockey Arena—Hy 59 South, Fergus Falls. 8 AM to 2 PM. VE testing, packet, Army MARS, satellite meetings. Demos, dealers, flea market, concession and more. Registration $4/door, $3/advance. 6' Tables $4. For information call (218) 826-6274 or write Keith McKay, N0FKF, Rt 1, Box 46, Battle Lake, MN 56515.

NEW JERSEY: April 15. "Flemington Hamfest 89", sponsored by the Cherryville Repeater Association, 8 AM in the Hunterdon Central High School Field House. Admission: $4 advance, $5 door. Children under 12 and XYLs free. Refreshments available from 6:30 AM. Advance tickets: Dave Hickson, KD2RC, 125 South Main St, Lambertville, NJ 08530. Tables: Marty Grozinski, NS2K, 6 Kirkbridge Rd, Flemington, NJ 08822. Information: (201) 788-4080 before 11 PM EST. VE testing begins at 10 AM, send FCC form 610, photocopy of current license, and a check for $4.75 (payable ARRL/VEC) to: Cherryville Repeater Association, VE Test Team, Box 308, Quakertown, NJ 08868. Talk in: 146.52, 147.975/375, 145.615/015, 222.52/224.12 and 449.85/444.85 MHz.

CONNECTICUT: April 16. The 6th annual Southington Amateur Radio Association's Flea Market, Southington National Guard Armory, 590 Woodruff Street, Southington. Admission $2. Children under 12 admitted free. 6' table space $8/advance; $10/door. For information on table space write SARA, PO Box 873, Southington, CT 06489. All classes of Amateur Radio exams. For pre-registration send info to Vinny Calandra, 44 Matthews Street, Southington, CT 06489. Talk in on 146.28/88, 222.68/224.28.

PENNSYLVANIA: April 16. AARG Hamfest and Computer Show, sponsored by the Appalachian Amateur Repeater Group, Lebanon Fairgrounds, Lebanon. Starts 8 AM. Admission $3.00. Indoor tables w/elec $5; w/o $3. Tailgating $2/space. Handi accessible. For information AARG, Homer Luckenbill, WA3YMU, 105 Walnut Street, Pine Grove, PA 17963. (717) 345-3780.

GEORGIA: April 22-23. Georgialina Hamfest, sponsored by the Amateur Radio Club of Augusta, Hippodrome, US 1 North, Augusta. Admission $3/advance; $4/gate. Covered arena. Tables $10, advance only. Acres of tailgating space. For information N4JA, POB 5943, Augusta, GA 30906.

OHIO: April 23. The North Coast Amateur Radio Club's third annual Swapfest, North Olmsted Community Cabin, 28114 Lorain Road, North Olmsted. 10 AM to 2 PM. Donation $2. Refreshments available. Nearby hotels and campgrounds. Talk in on 145.29R and 224.84R. For information Dan Sarama, KB8A, 15531 Rademaker Blvd, Brookpark, OH 44142. (216) 267-5083. Pauline Wells, KA8FOE, 5755 Burns Road, North Olmsted, OH 44070. (216) 779-8999.

DAYTON HAMVENTION: April 28, 29, 30.

OHIO: April 29. The 20th annual B*A*S*H will be held on Friday night of the Hamvention at the Conference Center (Madison Room) of the HARA Arena and Conference Center, same location as the Hamvention, starting at 7 PM. No admission charge. Free continuous entertainment. Hot dinner, sandwichs, snacks and beverages are available. Two exciting top awards and many others. Stay right at HARA when the Hamvention closes on Friday evening and meet your friends and join us for an evening of fun and entertainment. Sponsored by the Miami Valley FM Association, PO Box 263, Dayton, Ohio 45401.

NEW MEXICO: April 29 and 30. The Mesilla Valley Radio Club of Las Cruces will hold its 25th annual ham get together, the ZIA HAMFEST and BEANFEED at the Dona Ana Fairgrounds from 9 AM to 4 PM both days. Includes: great food, Ham Forums, VE exam, RV parking, exhibits, flea mart and more. Admission $5 and indoor tables $6. Contact: Joe Herring, WI5E, PO Box 234, Organ, NM 88052. Tel: (505) 382-5629.

MASSACHUSETTS: April 30. The Wellesley Amateur Radio Society's tailgate flea market, Wellesley Senior High School parking lot, 50 State Street, Wellesley. 9 AM to 2 PM. Admission $2. Handi accessible. Refreshments available. Talk in on 147.03 Wellesley Repeater. For more information David Kent, N2AWG. (508) 875-2126.

WISCONSIN: May 6. The Ozaukee Radio Club will sponsor its 11th annual Swapfest, Circle B Recreation Center, Highway 60, Cedarburg. 8 AM to 1 PM. Admission $2/advance; $3/door. 4' tables $2 each, advance only. Sellers setup 7 AM. For tickets, tables, maps, information send business SASE to ORC Swapfest, N5415 Crystal Springs Court, Fredonia, WI 53021. Talk in on 146.55 and 146.37/.97 repeater.

NEW YORK: May 6. The Putnam Emergency Amateur and Radio League will have their PEARLfest at the John F. Kennedy Elementary School, Foggintown Road, Brewster. 9 AM to 4 PM rain or shine. Admission $3. Indoor tables $8. Tailgating $5. Ham gear, VE exams, and more. Join us for a funfilled day. Talk in on 145.135 KG1O/R. For registration contact Terri Cullum, N2GWF, 40 Mile Hill Road, Highland, NY 12528 or Jim Morgan, KA2FIQ, 39 Overlook Road, Ossining, NY 10562.

ARIZONA: May 5-7. The Cochise Amateur Radio Association's annual Hamfest, Club training facility, Sierra Vista. Free tailgating. Exams available. Handi facilities. Talk in on 146.52 or 146.76. For information N7INK (602) 378-3155 after 6 PM or write CARA, PO Box 1855, Sierra Vista, AZ 85636.

SOUTH CAROLINA: May 6 and 7. 50th annual Greenville Hamfest sponsored by the Blue Ridge Amateur Radio Society, American Legion Fairgrounds, Greenville. Saturday 8-5; Sunday 8-3. Admission $4/advance; $5/gate. Walk-in license exams, large exhibit area, indoor/outdoor electronic and computer flea market, free parking, camping, prizes. For advanced tickets or information SASE to Blue Ridge ARS, POB 6751, Greenville, SC 29606.

WISCONSIN: May 13. Lakeshore Hamfest sponsored by Mancarad Radio Club, Manitowoc County Expo Center, Hwy 42-151 and I-43 on County Hwy R. Starts 8 AM. Vendors setup 7 AM. Tickets $2/advance; $3/door. Swap tables $3. Exams, refreshments, prizes. Talk in on 146.61 and 147.03. Camping available. Contact: Mancarad Radio Club, PO Box 204, Manitowoc, WI 54220.

WEST VIRGINIA: May 21. The 11th annual TSRAC Wheeling Hamfest/Computer Fair, Wheeling Park, 8 AM to 3 PM. WV's largest Hamfest. Dealers welcome. Free flea market, admission only. Free admission for women. Free admission for children 14 and under. Admission $3/advance; $4/door. To reserve space contact Sandi Williams, WC8P, 9 East High Street, Flushing, OH 43977 (614) 968-3652. For tickets TSRAC, Box 240, RD 1, Adena, OH 43901 (614) 5546-3930.

CALIFORNIA: May 21. HAMSWAP, sponsored by the North Hills Radio Club, Folsom Community Clubhouse, Folsom. 8 AM to 3 PM. FREE admission. Auction, tailgating, free parking, park, kids rides. Tables $6/each. No advance sales. Talk in on 145.19 and 224.78. Contact NHRC, PO Box 41635, Sacramento, CA 95841 or call Bob, WA6ULL (916) 983-2776.

NEW HAMPSHIRE: June 3. The Hosstraders Flea Market is back at the Deerfield Fairgrounds. Admission $5 per person. Friday night camping nominal; no admission before 4 PM Friday. Profits benefit Shriners' Hospitals, last year's gift over $20K. Wheelchair accessible. Questions or map SASE to WA1IVB, RFD Box 57, West Baldwin, ME 04091.

OPERATING EVENTS

"Things to do . . ."

April 14-28. The Thames Valley College will be operating a special event station GB2TVC to celebrate its becoming an independent college. We will operate on all HF bands and 2m in RTTY, AMTOR, SSB and CW modes. A special QSL card will be forwarded to all contact.

April 15-16: The Old Pueblo Radio Club will operate W7GV, the oldest continuously active callsign in Arizona, from 1500Z to 2400Z to commemorate 60 years of worldwide Amateur Radio operation on the 10 meter band. CW, phone FM, and packet gateways. For a QSL send your QSL and SASE to W7GV, Box 42601, Tucson, AZ 85733.

April 22: The North Carolina Chapter of the Triple States RAC will be operating special event station N4KVF 1400Z to 220Z at the site of Reed's Gold Mine, in commemoration of the 12th anniversary of this slate historic site, where gold was first discovered in the U.S. For certificate send #10 SASE to Walter Bastow, 484 High Rock Road, Gold Hill, NC 28071.

April 27-30. The Nebraska City Amateur Radio Club will operate special event station K0TIK from Arbor Lodge in Nebraska City, the home of J. Sterling Morton the founder of Arbor Day. 1400Z to 0000Z on upper portion of General phone bands, 80-15m and upper portion of 10m Novice phone band. For a certificate suitable for framing send 8x11 SASE and QSL to Barbara Nihart, President, Nebraska City ARC, 7731 Holdrege St, Lincoln, NE 68505.

April 29: W7UQ Centennial Reunion-on-the Air sponsored by the University of Idaho ARC. 14.230, 1900-2130 UTC; 28.400, 2130-2200 UTC, 7.230, 2200-0100 UTC. Help us celebrate the Clubs 60th year and the 100th anniversary of the University. Contact via callbook address.

The DeVry Amateur Radio Society has been a national VEC since February 23, 1984. We have over 40 testing groups nationwide and are continuing to grow. We offer a program based upon integrity and creativity. The forms our VE's are required to fill out are simple and to the point. We also reimburse all our testing groups for out-of-pocket expenses. If you would like to start a DeVry VE team in your area just call 1-800-327-2444, ext 2221 or 1-312-929-8500 or write DeVry VEC, 3300 N. Campbell Avenue, Chicago, IL 60618.

NORTH COAST ARC 1989 LICENSE EXAMS. 12:30 PM, Saturdays February 11, April 15, June 10, August 12, October 14, December 9. N. Olmsted Community Cabin, S of Lorain on W. Park. Novice thru Extra. Walkins allowed. Talk in 145.29 repeater. For information Dan Sarama, KB8A, 15591 Rademaker Blvd, Brookpark, Ohio 44142. 267-5083 or Pauline Wells, KA8FOE, Rick Wells, K8SCI, 777-9460/779-8999.

AMATEUR RADIO CLASSES: For those people interested in obtaining a Novice (basic level) Ham license or upgrading to Tech/General, the Chelsea Civil Defense, in cooperation with QRA Radio Club, will sponsor Amateur Radio Communications classes evenings at Chelsea High School starting MARCH 7, 1989. For more information write Frank Masucci, K1BPN, 136 Grove Street, Chelsea, MA 02150. Please enclose your telephone number.

THE MIT UHF REPEATER ASSOCIATION and the MIT Radio Society offer monthly HAM EXAMS. All classes Novice to Extra. Wednesday, APRIL 19, 7 PM, MIT Room 1-150, 77 Mass Avenue, Cambridge, MA. Reservations requested 2 days in advance. Contact Ron Hoffmann at (617) 484-2098. Exam fee $4.50. Bring a copy of your current license (if any), two forms of picture ID, and a completed form 610 available from the FCC in Quincy, MA (617) 770-4023.

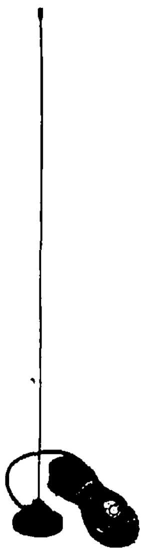
NEW products

Antennas and mounts from Valor Enterprises

The model PAQM "communications extender" mobile, 2-meter VHF antenna provides mini quarter-wave reception. It installs easily with a 2-inch magnetic mount, 12 feet of cable, and a BNC connector (supplied). The unit can also be modified for 220 and 450 MHz.

Model PA270, two-plus-two, is a dual-band antenna for 146 and 450 MHz. It includes silver-plated spring-loaded contacts and will work on scanner radio UHF/VHF bands.

The Model PUC 450 UHF collinear gain antenna features silver-plated spring loaded contacts and 100-watt rated Motorola base. This unit has a 450 to 470-MHz frequency range.



For additional information contact Valor Enterprises, Inc., 185 West Hamilton Street, West Milton, Ohio 45383.

Circle #311 on Reader Service Card.

New switch for lightning protection

MFJ Enterprises, Inc. presents its new MFJ-1704 four-position antenna switch with lightning protection for $59.95.

This 50-ohm switch handles 2.5 kW PEP, 1 kW CW with low SWR. Isolation is rated from better than 60 dB at 30 MHz to better than 50 dB isolation at 500 MHz. Insertion loss is negligible.

The lightning protection device inside has cavity construction and metal strip leads that prevent chafing and shorting problems. Unused positions are automatically grounded, or the center ground position can be selected.

Contact MFJ Enterprises, Inc., PO Box 494, Mississippi State, MS 39762 or order toll free at 800-647-1800.

Circle #312 on Reader Service Card.

New TS-430 tuning upgrader

International Radio and Computers, Inc. announces the TS-430 Tuning Upgrader.

Stock TS-430s have just two manually selected tuning speeds: 19 kHz per tuning knob revolution and 100 kHz per revolution when the step button is depressed. The tuning upgrader adds a slower fine-tuning speed of 2.5 kHz per revolution. The upgrader requires three above-board solder connections and two plug-in connections.

The tuning upgrader also operates when the step button is depressed. In this mode, it automatically selects between 25-kHz per revolution and 100-kHz per revolution; the switchover point occurs at approximately 0.8 turns per second.

The unit uses low-drain CMOS circuitry, comes wired and tested, and has a 6-month warranty. The price is $34.50 plus $5 shipping and handling in the U.S., $15 elsewhere. Use Reference no. 215.

The TS-430 is available from International Radio and Computers, Inc., 751 South Macedo Boulevard, Port St. Lucie, Florida 34983.

Circle #313 on Reader Service Card.

Tower standoff brackets

IIX Equipment, Ltd. offers tower standoff brackets. These brackets let you mount two or three large antennas 40 inches off the tower face. Attachment clamps are adjustable to fit up to 4-inch tower legs; the brackets are drilled to fit 25G, 45G, and 55G towers. Bracket arms can be spaced any distance apart to accomodate the antennas. Brackets are hot-dipped galvanized and the necessary hardware is supplied. The brackets are available in two and three antenna models. The SO-12 Standoff Bracket (for two antennas) is $115.50 and the SO-13 Standoff Bracket (for three antennas) is $144.50. The brackets are shipped by U.P.S.

For more information contact IIX Equipment, Ltd., PO Box 9, Oak Lawn, Illinois 60454.

Circle #314 on Reader Service Card.

PCSP-1 power cord surge supressor

American Voltage Products, Inc. has introduced the PCSP-1 power cord, offering built-in surge protection for standard computers and electronic equipment. Unlike plug-in surge protectors, the PCSP-1 is less likely to be destroyed by furniture movement or unauthorized removal.

The PCSP-1 has 210,000 watts of protection. All three legs are protected and the unit glows while in operation. The PCSP-1 sells for under $20.

For more information contact American Voltage Products, Inc., 18 Morse Drive, Essex Junction, Vermont 05452.

Circle #315 on Reader Service Card.

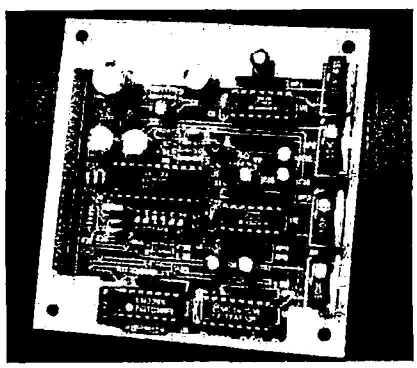
UAI-20 repeater audio interface

Creative Control Products has added the UAI-20 Universal Audio Interface board to its line. It is a repeater and link audio mixer featuring CTCSS decode, DTMF mute, and link monitor-mix control.

Audio inputs consist of repeater, link, control receiver, CW/tone, CTCSS tone, and an auxiliary input for other audio sources. Audio outputs include: repeater, link, and a DTMF output for the DTMF decoder on your controller.

Control inputs consist of repeater Carrier Operated Switch (COS), CTCSS mode, DTMF mute, and an auxiliary output from your controller for the link mute function. The CTCSS decoder output switches to the selected output level upon receiving the correct CTCSS tone.

The UAI-20 has an audio filter, which removes the sub-audible tone from the repeater receiver audio path. Automatic muting of the repeater receiver is provided when the selected CTCSS tone hasn't been decoded. CTCSS tones are selected by configuring the 6-position DIP switch to the appropriate CTCSS frequency.



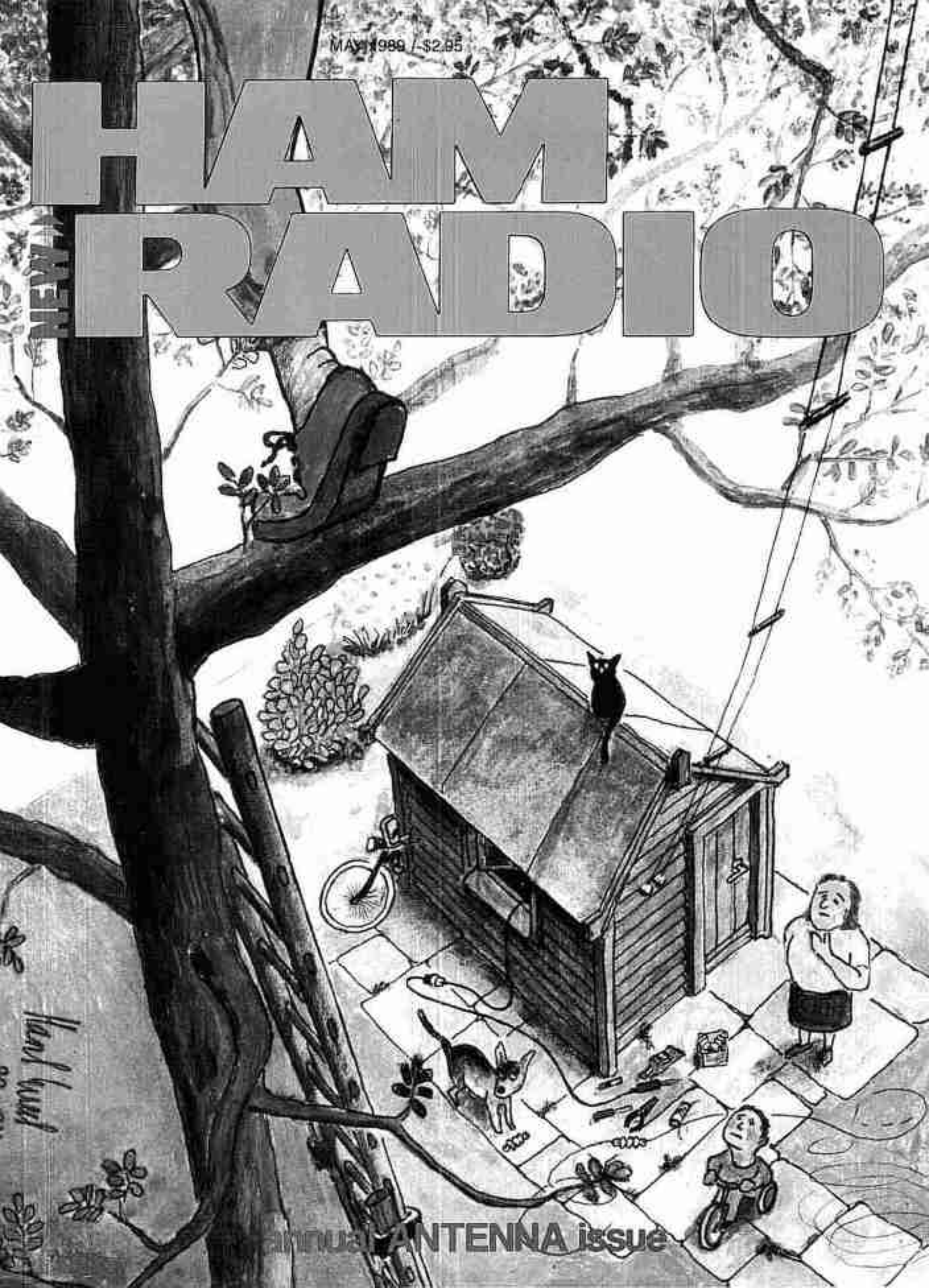
An assembled, tested UAI-20 with manual is available at an introductory price of $89 plus shipping.

For more information, contact Creative Control Products, 3185 Bunting Avenue, Grand Junction, Colorado, 81504.

Circle #316 on Reader Service Card.

MAY 1989 / $2.95

NEW HAM RADIO



annual ANTENNA issue

HAM RADIO

MAY 1989
volume 22, number 5

KZ3K, page 49

W6SAI, page 74

See page 25 for the winners of March's Weekender contest.

Cover Illustration: Hans Evers, PA0CX

FEATURES

DEPARTMENTS

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William W. Eitel, W6UF
1908 - 1989

W6UF: Amateur Radio frontiersman

To say "It can't be done" was a challenge to William W. Eitel, W6UF. In 1927 it was thought that the new 10-meter band was workable for line-of-sight transmissions only, as the 5-meter band seemed to be. W6UF was one of the first stations on the band, determined to prove that 10-meters was good for long distance communication. In a few weeks he was running daily skeds with W1CCZ and ZL2AC, establishing beyond a doubt the DX qualities of the new band. His home-made transmitter used a crystal he had ground from a chunk of quartz found in a mountain stream. He saved money for weeks to buy an 852 tube for the 150-watt amplifier stage. He built a two-tube regenerative receiver. His efforts were summarized in *QST* in January 1929. Ten meters was not like the "ultra-high" frequencies! It was a DX band!

This was an auspicious beginning for a 20-year-old lad with a consuming curiosity about radio communications. His biggest problem was the cranky 852 tube; it required enormous plate voltage to work properly at 10 meters. He decided he could build a better tube, which would work at a reasonable plate potential.

His chance came in 1933 when he went to work for a vacuum tube manufacturer in the San Francisco area. Bill, along with Jack McCullough, W6CHE, developed a low-voltage, high-current tube that proved superior to the 852. Unfortunately, the company (a marine communication business) wasn't interested in selling tubes to Amateurs , so tube sales languished. Bill and Jack soon left the company, and in 1934 started a new enterprise — Eitel-McCullough, Inc. Their goal was to build reliable "EIMAC" tubes that would operate at higher frequencies than anything available. They borrowed $5,000 and designed a revolutionary new triode tube, the 150T.

This was the start of something big. EIMAC tubes were quickly adapted for commercial and military use, and the little company prospered. Within a decade it became the United States' leading producer of power electron tubes and related devices. The combination of Jack (the planner and designer) and Bill (the hands-on activist) was fortuitous. The right guys with the right products at the right time!

Bill's interest in Amateur Radio, although curtailed by the effort of building a company and the demands of war production, never flagged. Bill and Jack went out of their way to enlist Radio Amateurs in the company, to encourage them in the new communication industry, and to develop new tubes for Amateur Radio.

Over the years, Bill never lost his inventor's curiosity. His interest in advancing the frontiers of Amateur Radio continued. In 1961 the EIMAC Radio Club, under the leadership of Bill, Jack, and Hank Brown (W6HB), established the first Amateur two-way "moonbounce" contact on 1296 MHz with W1FZJ.

Bill was a member of the Northern California DX Club and Project OSCAR. He donated time, equipment, and money to make the early OSCAR satellites successful. If there was a job to be done, he'd do it. His enthusiasm and support were often all that kept the early OSCAR satellite program from foundering. He was a remarkable, enthusiastic leader in the best sense of the word. He was an excellent operator, CW or phone, and set the pace for Amateurs many years his junior.

Upon retirement, Bill moved to Dayton, Nevada and set up his own experimental laboratory, continuing to work on ideas that interested him. He was a life member of the ARRL, Project OSCAR, and the 5-Star Operator's Club. He was elected to a fellowship in the Radio Club of America.

He passed away in February 1989 at the age of 81. His accomplishments were many. In addition to being an active Radio Amateur, inventor, company founder, and executive, he was a good companion. He left behind a multitude of friends who mourned his passing. He left his mark in electronics and the Amateur world. His discontent with the status quo drove him to succeed when others dropped by the wayside. His inquisitive mind made him an alert problem solver. Along the way he helped others. He was an American original: a self-educated small-town boy who grew up in a turbulent era of rapid and productive scientific growth — and mastered his world.

We will all miss him. 73, Bill, and SK.

Bill Orr, W6SAI

PUBLISHER'S LOG

You are now looking at the final step in our redesign program here at *Ham Radio*. It represents well over a year of very hard work on the part of a large number of people including many of you, our readers.

We started with a new editorial staff. Next, we interviewed a sizable sample of both subscribers and non-subscribing Amateurs to find out where you felt our strengths and weaknesses were. What should be done to make the best Amateur Radio magazine even better?

By September of last year you saw phase one, with our new logo and a redirected emphasis on practical construction articles and shorter technical and tutorial pieces. We also instituted the feedback cards to find out just what you liked and didn't like about our many changes.

We listened, we fine tuned, and we listened again. All the while, those responsible for the design of the magazine were hard at work coming up with a product which would be more eye pleasing than ever before. One that would, at the same time, be very efficient in helping the reader to get the most from each page they read.

I'm very happy with this finished product, but I'm even more proud of the many people who have gone the extra distance to bring all of this together. Thanks must go to the whole *Ham Radio* staff; to those at Wallace Press, our typesetter; and to Anne Desmarais, our design consultant.

The formal program is now over, but the striving for improvement will never stop. If you have any good ideas or suggestions, we're always open to them. Let us know what you think.

Skip Tenney, W1NLB

Comments

A good laugh

Dear HR

Your February issue arrived in the mail yesterday and, after a look at the cover, I had one of the best laughs in a long time!

It's hard to tell what the piece of gear is that has your "cover ham" looking so apprehensive, but I immediately thought of the old SB-104 that is sitting on my table; the schematic is just about the same size, so big that I finally pinned it on the wall for convenience.

So congratulations to you and your artist for identifying with us readers who enjoy (?) digging into gear!

Ray Burke, VE1BFG, Bathurst, New Brunswick, Canada

A good recipe— blending old with new

Dear HR

My good friend, Bert Cliff, W2QN, gave me a one year subscription to HR for Christmas. Today, for the first time since a lapse of almost ten years, I received the January issue in top condition.

I could not help but sit down and work through the magazine as soon as I could do so. If I am not mistaken, you are endeavoring to create a blending between the former *Ham Radio Horizons* and *Ham Radio*, which I followed for many years. My first impression is that you have achieved an excellent mixture. I, therefore, would suggest that you continue along this line, and I am eagerly looking forward to the following issues.

I have included my magazine evaluation card. I found the article written by Joe Reisert, W1JR, "VHF/UHF World," of special interest since it may well have put quite a dent into my HF one-sided-ness.

Congratulations to Joe Carr, K4IPV, for his splendid article on "Writing the Technical Article." I was the last editor of the pre-war German DASD Amateur Magazine *CQ* in 1941/43. I do wish I could have read Joe's advise then, or at least in 1947 when I started my side-line career of writing pieces for our first ham mag *QRV* after the war.

Albert Heine, DK7CN, D-8990 Lindau, W. Germany

Food for thought

Dear HR

I have just read a letter by AA6FW in your magazine of February 1989.

I am surprised. Perhaps the radio operators in San Diego are different from those here.

As an Amateur who is a relative newcomer (about 6 years), currently 49 years old, a V.E., and a volunteer operator at a museum demonstration station, I can make the following personal observations:

- I was stimulated to get my license by a man years my junior, not a grandfather.
- The growth of Amateur Radio, in this area, is positive and being aided by classes conducted by radio clubs in Delaware, Pennsylvania, and New Jersey.
- The newcomers are of all ages, and it's often a family affair.
- 5 WPM code can be passed by anyone who makes even a minimal effort. Of course code is an entrance requirement, but, so is a lot of other knowledge — frequencies, rules, regulations, electronics, etc.

Now, if the code requirement is eliminated under the guise of "too hard, scares them away," "not necessary," or some other feeble excuse, what do you suppose might be the next requirement to go — perhaps questions about...oh shucks, why even have an examination! "All an Amateur does is push a bunch of buttons." I can hear it now.

Merrill Jay Mirman, D.O., KT3Z, Springfield, Pennsylvania

IMPROVED HIGH-PERFORMANCE YAGIS FOR 432 MHZ

Obtaining the most from a design

By Steve Powlishen, K1FO, 816 Summer Hill Road, Madison, Connecticut 06443

In the July 1987 issue of *Ham Radio* Magazine,[1] I described a high-performance 432-MHz Yagi design which I built from a Cushcraft 424B. This design improved the radiation pattern and wet weather performance of the original and offered a substantial increase in forward gain.

I gave two versions of the design. The first used 24 elements on a 17′ boom. K2OS, WA3FFC, and W7HAH now use this Yagi on EME. All of them have reported on-air EME performance improvements. A number of tropo operators have also been pleased with the results of my modification. But tropo performance is much harder to quantify and prove than EME performance. The Yagi works so well that several operators have chosen to build it from scratch. As it stands, the 24-element Mark 3 Yagi is still the final version for this boom length. I examined the possibilities of further optimization and found that I wouldn't achieve more than an additional 0.1 dB in theoretical gain. Unfortunately, I could obtain this gain increase only at the expense of pattern deterioration and increased resistive losses.

The second version of my design used a 24′ extended boom and had 32 elements. (See **Table 1** for element length and spacing dimensions.) This extended version has also been used successfully on EME, both in NC1I's 16-Yagi array and my 4-Yagi portable EME array. NC1I used the 4-Yagi array in his Rhode Island and Vermont EME DXpeditions. WA9FWD has used a similar 4 × 32 element Yagi array on EME. (He's now replaced it with an even longer 36-element model.) In the July 1987 *Ham Radio* article,[1] I mentioned that while the 24-element design was a third-generation effort, the 32-element model I described was a second-generation effort which still had room for improvement. I also gave alternative, but untested, director lengths for a potentially improved 32-element Yagi and an even longer 38-element model (both third-generation designs).

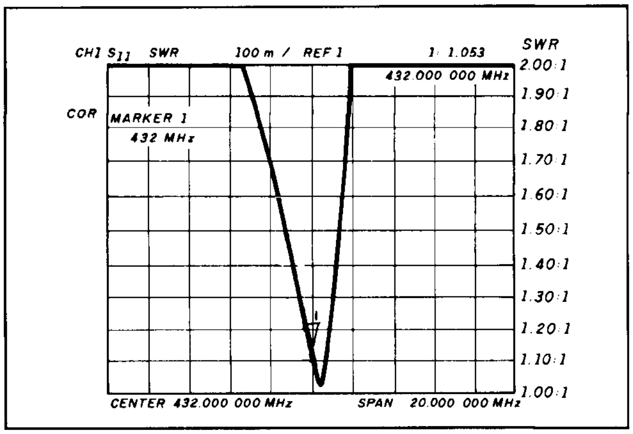
The revised design

Here are the final improved and tested dimensions for the 32-element Yagi. It's called the 32-element Mark 4 Yagi and is the fourth major revision of this design. The improvements to this 32-element Mark 4 Yagi over the earlier published version are:

- Improved radiation pattern, primarily in the rear lobes.
- Greatly improved VSWR bandwidth and wet weather performance.
- Reduced element resistive losses.
- Higher forward gain (~0.2 dB).
- Higher center frequency tuning for improved array performance.

I've also detailed a fully tested 27′6″ long model.

FIGURE 1



Resonant frequency and VSWR bandwidth of the original 32-element Mark 2 Yagi.

Why improve it?

I got the impetus for these changes while helping to assemble NC1I's 16-Yagi EME array. I had determined the driven element T match dimensions by testing a Yagi mounted on a pole in my back yard. When we started checking the driven element matches of the individual Yagis, mounted in place with the other Yagis in the 16-Yagi array, the dimensions for an acceptable VSWR didn't agree with my earlier work. A similar but lesser match problem arose in the 4-Yagi portable EME array. And, although wet weather performance of NC1I's 16-Yagi array was greatly improved over the unmodified Yagis, the wet weather VSWR performance wasn't as good as we'd hoped.

I examined a sample 32-element Yagi on a Hewlett-Packard 8753A network analyzer; it revealed a very narrow match bandwidth. As you can see in **Figure 1** (a printout of the network analyzer measurement), the under 1.2:1 VSWR bandwidth is approximately 1 MHz. The driven element is under 2:1 VSWR over a 5-MHz span. This was substantially narrower than that displayed by the 24-element Mark 3 Yagi. My attempts to improve the match bandwidth on the 32-element Mark 2 Yagi by driven element adjustments alone were unsuccessful. With the help of the network analyzer I found a "natural" match frequency with acceptable bandwidth centered at 423 MHz. Previous work on the 32-element Yagi had shown that shortening all of the elements to raise the center frequency 9 MHz would lower the gain by several tenths of a dB.

I continued my computer analysis. As described in the *Ham Radio* article, the orginal computer analysis for the version 2 Yagi was done using a variation of the WB3BGU program. Because of the limited accuracy of this program, I had to make element adjustments to control the radiation pattern. Investigations done with MININEC showed excessive currents in the first few directors. These directors were also quite long when compared with some other designs. In fact, the director string could be divided into three parts: the first few directors which were tuned too low in frequency; the middle set of directors which were tuned too high in frequency; and the last directors which were tuned close to the correct frequency, but slightly low. Further analysis and work on other long Yagi designs[2] showed that a smooth

TABLE 1

Dimensions K1FO 24', 32-element Mark 4 Yagi.

Element Spacing (inches)	Element Length (mm)	Boom	Element
1.000	348		REF
5.250	336		DE
7.875	323		D1
11.563	314		D2
16.813	309	1"	D3
23.563	305		D4
31.875	301		D5
42.125	297		D6
52.375	294		D7
62.625	292		D8
72.875	290		D9
83.125	288		D10
93.375	286	1 1/8"	D11
103.625	285		D12
113.875	284		D13
124.125	283		D14
134.375	283	1 1/4"	D15
144.625	282		D16
154.875	280		D17
165.125	279		D18
175.375	278	1 1/8"	D19
185.625	277		D20
195.875	276		D21
206.125	276		D22
216.375	275		D23
226.625	274		D24
236.875	273		D25
247.125	273	1"	D26
257.375	272		D27
267.625	272		D28
277.875	271		D29
288.125	271		D30

minor lobe pattern coincided with a good current distribution. I used this information in the 24-element Mark 3 Yagi design.

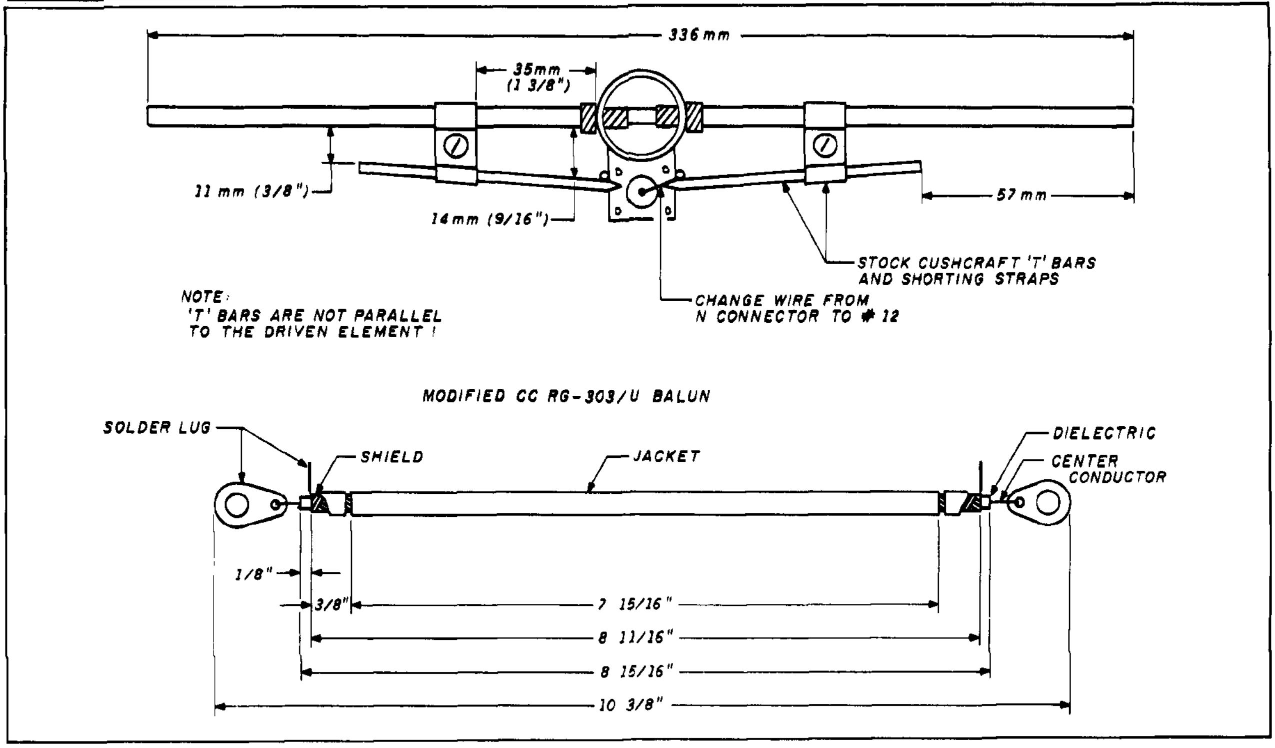
Design details

Up to this point, I'd been doing all my work on the Yagis in English dimensions. I needed an easier measurement method because I was spending considerable time building test Yagis. Metric dimensions for the element lengths were the answer. Not only is the millimeter an easier unit for working with 432-MHz Yagis, but the size of a millimeter (.039") allows for a smoother element taper — without the confusing fractional units.

All element spacings are the same as they were in the earlier versions; they are given in inches. I spent a fair amount of time looking at other spacing arrangements. It was possible to obtain slight performance improvements, but only with extensive spacing changes. These changes would make additional modification and upgrading difficult, defeating my purpose.

To make this improved design, I first converted the English lengths used in the 24-element Mark 3 Yagi to metric dimensions. Next I rounded these millimeter-sized directors to whole millimeters. Then I smoothed out the large changes in director lengths. The computer analysis on MININEC looked promising, but there was a substantial frequency

FIGURE 2



Construction detail of the 32-element Mark 4 driven element using 424B parts.

shift as a result of these manual length changes. I shortened the lengths to center the Yagi at the desired frequency.

Now I had to perform the final length optimization using MININEC. This was a painfully slow process because of the computation time required by the computer available to me at that time. A quick look at the Yagi modeling with four segments required over 2 hours; a more accurate examination using eight segments took almost 8 hours. Consequently, I was able to make only a few element adjustments each day. I'd make an overnight high-accuracy run to ensure that I was still on the right track. Fortunately, the machine I use now solves the problem over six times faster.

When I started this project 4 years ago, I was using a simple program. The original design objective was to increase the Yagi's gain while creating a clean radiation pattern. My current design process adds to the original goals with the following requirements:

- Very high forward gain per boom length.
- Very clean radiation pattern.
- Wide gain bandwidth.
- Acceptable dry and wet weather performance.
- Good driven element match bandwidth.
- Reasonably high natural driven element impedance.
- Good director current distribution.
- Low resistive losses.

Knowledgeable use of the original program can get you 80 percent of the way to a good Yagi design. But the new requirements have rendered my first program obsolete, as it is unable to get all the way to an optimum solution. More complex programs, along with the all-important post-computer optimization steps, now take you 95 percent of the way to the perfect Yagi.

After finalizing the computer-generated dimensions, I began to build and test the project. As I had already built and tested a number of Yagis, I needed to make adjustments only to the driven element and director 1.

Construction

The Yagi's mechanical layout is the same as originally described in the July 1987 *Ham Radio* article. Elements are mounted on plastic bushings which insulate them from the boom sections they extend through. The element ends are chamfered like those of the earlier Yagis. Supports keep the boom from sagging unacceptably. I suggest you review my earlier article before attempting to build these Yagis.

I compared driven element T matches constructed from the original Cushcraft parts used on the 24-element Yagi, with T matches using no. 12 T wires and a UT-141 balun like those of the 32-element Mark 2 Yagi. I obtained similar dry weather matches and match bandwidths with both driven element arrangements. Wet weather performance was slightly better with the no. 12 T wires. A slight adjustment to the balun length made it correspond to an electrical half wavelength. This improved the Yagi's pattern balance.

Figure 2 details the driven element construction using the original Cushcraft parts. Note that the balun must be shortened by 1 inch. As with the 24-element Yagi, I didn't use the original rectangular black spacers and I changed the jumper from the N connector to the T match bar to no. 12 to get a proper match. For the best match don't place the T bars parallel to the driven element.

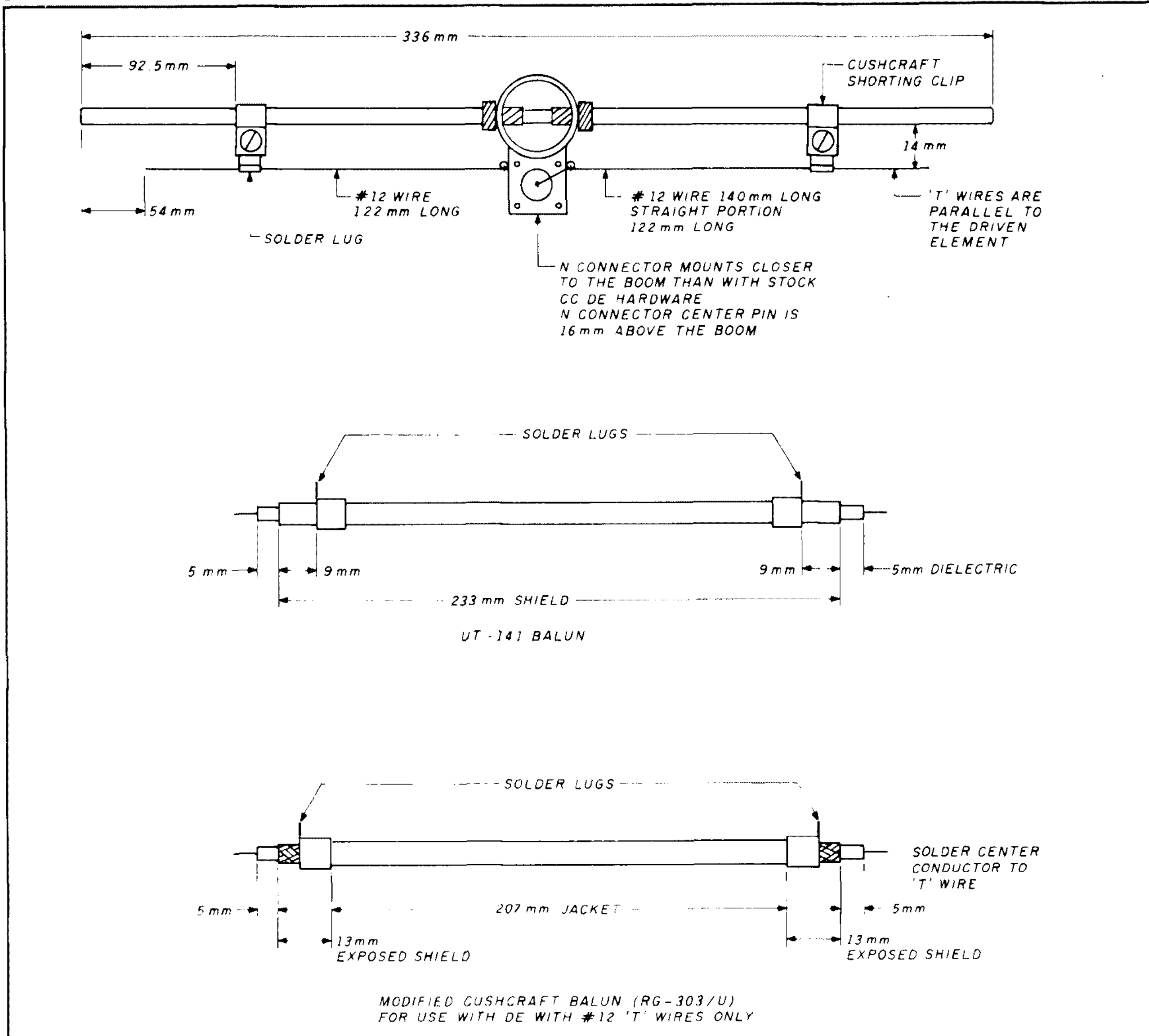
The second version of the driven element is shown in **Figure 3**. It uses no. 12 T wires in place of the original 3/16" diameter T bars. This allows for a greater natural impedance setup. I prefer this arrangement because the shorting straps are farther out on the driven element, away from the high-current point. I tried baluns made from UT-141 solid copper shield coax and RG-303 (like the original 424B) with similar results. If you make the balun from RG-303 you'll need to use a set of dimensions different from those used with the first driven element arrangement. I thought it was desirable to eliminate the original solder lugs and solder the center conductor directly to the T match wires instead.

Performance

The computed E and H plane patterns for the 32-element Mark 4 Yagi in **Figure 4** show a very smooth lobe structure. The first sidelobes are 1 dB stronger than those in the original version. This seemed an acceptable tradeoff for a smoother overall lobe structure and significantly lower rear and mid-H plane lobes, in combination with higher overall gain. Calculated gain on MININEC is 17.9 dBd (20.1 dBi). Because of program inaccuracies and resistive losses, the real gain of the Yagi is closer to 17.8 dBd (19.9 dBi) — still an excellent figure for the boom length. DJ9BV examined the Yagi design using the more sophisticated NEC program. His results gave an excellent pattern correlation. The NEC-calculated gain figure of 17.8 dBd (19.9 dBi) also agrees closely with antenna measurements.

On the antenna range, the new model consistently measures about 0.2 dB higher than the earlier 24' long version. It also measures about 0.4 dB higher than my "high-gain" reference Yagi, the KLM 432-30 LBX. This places the real-

FIGURE 3



Construction detail of the 32-element Mark 4 driven element using no. 12 T wires. Further details for modifying the Cushcraft Balun for use with the no. 12 T wire match.

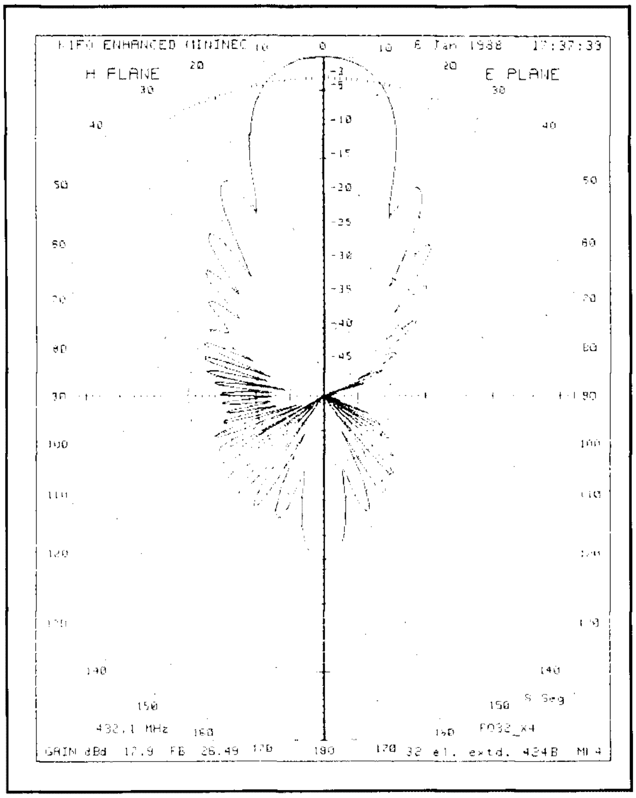
world gain of the new 32-element Mark 4 Yagi at about 17.8 dBd (19.9 dBi). Earlier measurements with the Mark 2 Yagi were slightly optimistic; the real-world gain for this version was about 17.5 dBd. (This has also been confirmed by NEC analysis.)

Array temperature is an important parameter on EME and for high-performance tropo stations. Array noise is the combination of noise received by the array (manmade or natural) and the noise generated from resistive losses in the material used to make it. DJ9BV calculated that an array of four of the 32-element Mark 4 Yagis pointed at cold sky has a noise temperature of 25K. This figure is 5K lower than the original Yagi design — a significant number on EME. Array noise measurements, using earth to cold sky and stellar sources to cold sky, place the array temperature somewhat higher than the calculations. Measured array temperatures for four Yagis arranged 2 × 2 are about 30K for the new Mark 4 Yagi, and about 37K for the old version.

To calculate the overall system temperature, you have to add the phasing line, relay, and balun losses, and the receive system noise temperature to the array noise. For a high-performance EME system with very low loss phasing lines (like the Andrew Heliax™ and a 25K preamplifier), this reduced array temperature would provide an additional 0.5-dB signal-to-noise improvement on receive over the original 32-element Yagis. Including the additional gain of the improved design, you can expect to hear your own moon echoes almost 1 dB stronger — a significant improvement for no array size increase.

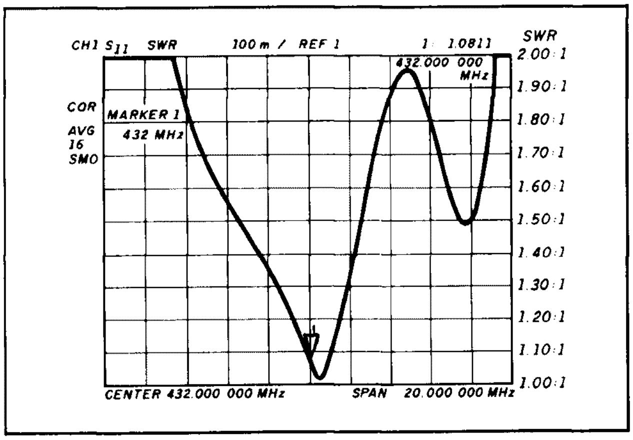
Figure 5 is a network analyzer plot of the driven element match. When you compare this with **Figure 1** (the same plot for the original 32-element Yagi) you can see that the

FIGURE 4



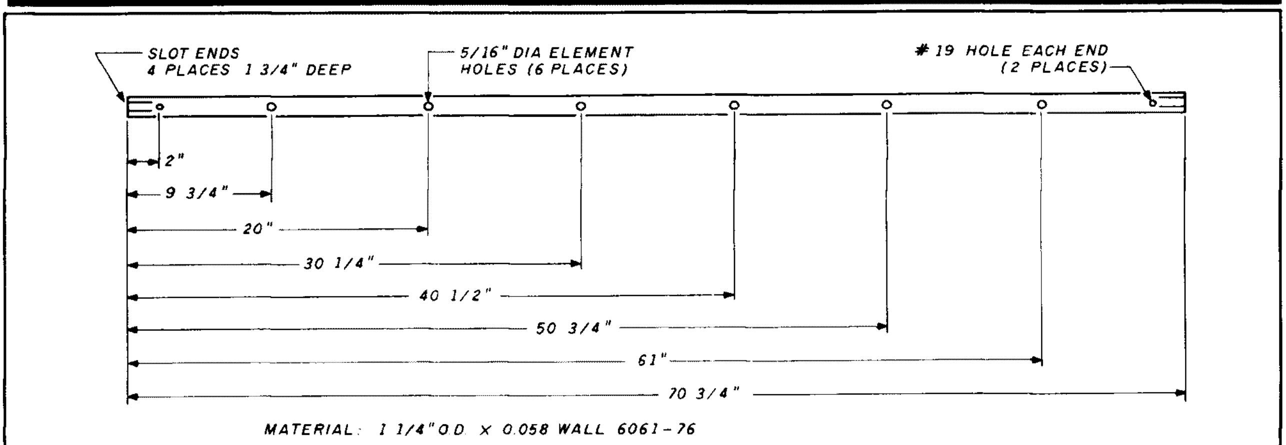
Calculated E and H plane patterns for the K1FO 32-element Mark 4 Yagi.

FIGURE 5



Resonant frequency and VSWR bandwidth of the improved 32-element Mark 4 Yagi.

FIGURE 6



Element mounting dimensions for the center section of the boom for the 36-element extended modified 424B Mark 4 Yagi.

match bandwidth is much broader. On the 32-element Mark 4 Yagi, the SWR is now less than 1.2:1 for almost 2.5 MHz. This is 2-1/2 times wider than the original. The SWR is less than 2:1 over 16 MHz, or more than 3 times greater than the earlier version.

With the revised dimensions, the 32-element Yagi behaves well when wet. The VSWR curve shifts down in frequency approximately 2 MHz under simulated heavy rain conditions. This raises the SWR to a still acceptable 1.35:1 when the antenna is very wet. This is a significant improvement over the 32-element Mark 2 Yagi, which would show about a 2.2:1 VSWR in heavy rain.

Proper stacking distances for the 32-element Mark 4 Yagi are 82 inches in the E plane and 78 inches in the H. At these distances, the stacking gain (before phasing line losses and mechanical errors are factored in) is over 2.9 dB in each plane. A 4-Yagi EME array using low-loss phasing lines would have 23.3 dBd (25.5 dBi) array gain. This is more than adequate to work a number of different 432-MHz EME stations. An 8-bay 32-element Yagi array has enough gain to give you a standout EME signal.

A longer 36-element version

NC1I did his portable EME operations in the summer, usually the worst time of year for EME. Although the original 4 × 32 element Yagi array performed well, I wanted a little extra performance without having to add more Yagis. I chose the 27-1/2′ length because it was the minimum size increase which would make a significant performance improvement. (See **Table 2** for element length and spacing details.)

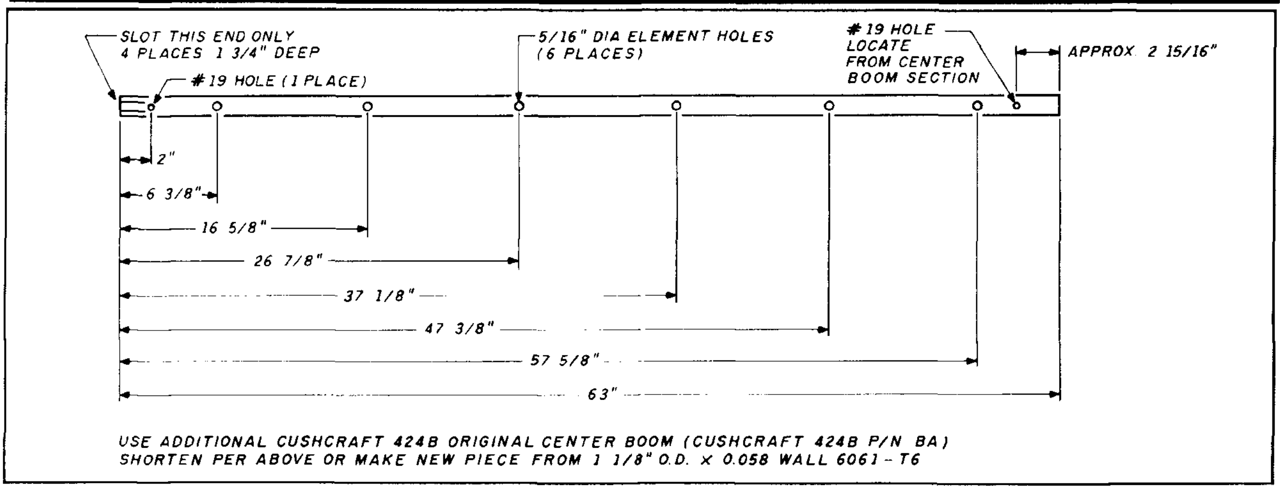
Electrically, the design is virtually identical to the 32-element Mark 4 Yagi. Mechanically, the changes are a little more detailed. I built a 6′ long 1-1/4″ diameter center boom section from scratch for the long Yagi. I reinforced this new center section with a 1-3/8″ outer diameter, 0.058″ wall thickness, 24″ long piece of 6061-T6 aluminum tubing. The 1-3/8″ diameter tube is centered at the mast mounting point. This arrangement gives you a very rugged (though slightly heavy) boom section.

TABLE 2

Dimensions K1FO 36-element Yagi 27′4-1/8″ boom.

Element Spacing (inches)	Element Length (mm)	Boom Diameter	Element
1.000	347		REF
5.250	327		DE
7.875	322		D1
11.563	313		D2
16.813	308		D3
23.563	304	1″	D4
31.875	300		D5
42.125	296		D6
52.375	293		D7
62.625	291		D8
72.875	289		D9
83.125	287		D10
93.375	285		D11
103.625	284	1 1/8″	D12
113.875	283		D13
124.125	282		D14
134.375	282	1 1/4″	D15
144.625	282	1 3/8″	D16
154.875	281		D17
165.125	279		D18
175.375	278	1 1/4″	D19
185.625	277		D20
195.875	275		D21
206.125	275		D22
216.375	274		D23
226.625	274	1 1/8″	D24
236.875	273		D25
247.125	273		D26
257.375	272		D27
267.625	271		D28
277.875	270		D29
288.125	270		D30
298.375	269	1″	D31
308.625	269		D32
318.875	268		D33
329.125	268		D34

FIGURE 7



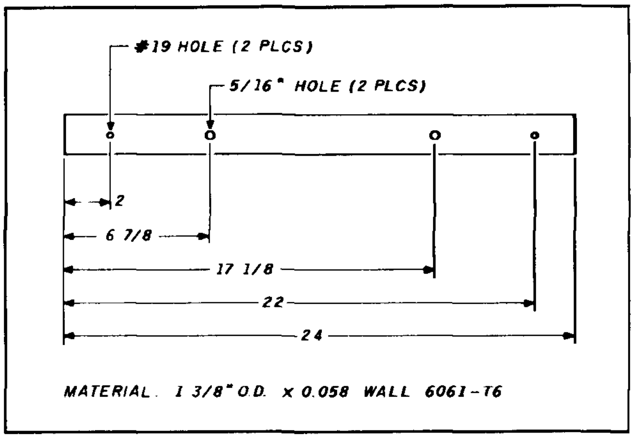
Detail for the new no. 2 rear boom section for the 36-element extended Mark 4 Yagi.

Though the doubled-up center piece may seem like overkill, it's very easy to bow a 0.058" wall tube when you tighten the mast bracket U bolts. A few degrees of bend in the boom may not be noticeable on a short Yagi, but when you translate this bend to a 27-1/2' long boom it becomes a significant curvature.

The new center boom section is detailed in **Figure 6. Figure 7** describes boom section no. 2 (between the rear and the middle section). You can make this second boom section from a spare 424B original center section, or from scratch. Just follow the drawing and use 1-1/8" diameter × 0.058" wall aluminum tube. The center boom reinforcing piece is shown in **Figure 8**.

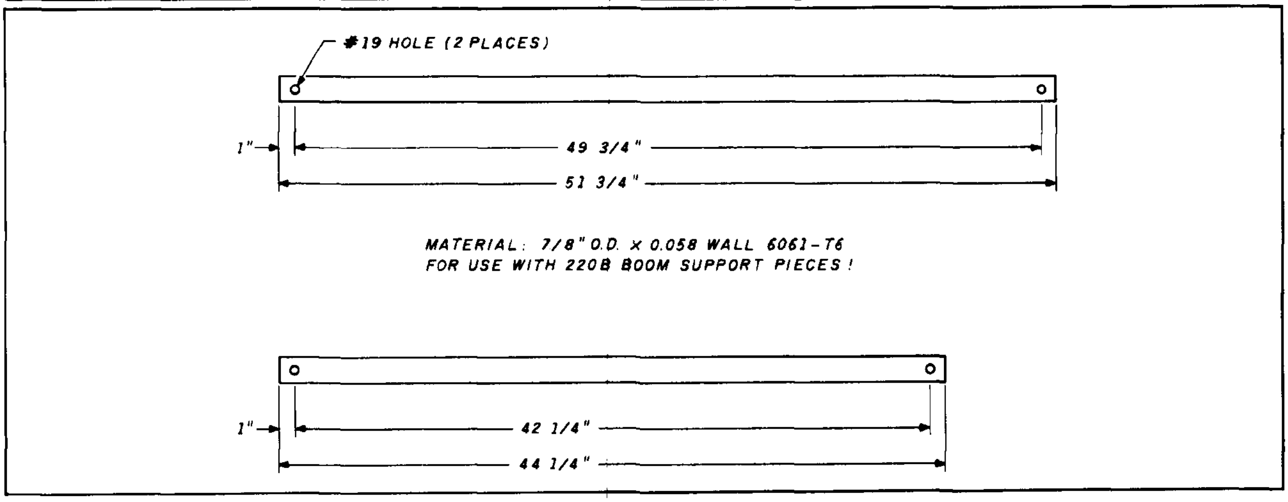
I made new pieces for the boom supports so I could extend them. I positioned the mast mounting point for the boom supports 30" from the boom. This creates a large enough angle and prevents overstressing the supports. Like the earlier Yagis, I used old-style Cushcraft 220B bent support pieces with longer homemade center sections. **Figure 9** shows these new boom support splice pieces. Cushcraft has since changed the design of their boom supports. If you don't want to make your own supports from scratch, Cushcraft 4218-XL boom supports will do the job.

FIGURE 8



Detail for reinforcing the center boom section of the 36-element extended Mark 4 Yagi.

FIGURE 9



Detail for the boom support pieces on the 36-element extended Mark 4 Yagi.

Electrical changes

You'll notice that the element lengths start out 1 mm shorter than on the 32-element Mark 4 Yagi. I changed the length to keep the gain center frequency in the right place. Remember that the Yagi's center frequency oscillates up and down as you add directors. Tapered designs like this one minimize the effect, but the trait still exists.

The driven element was easy to set up for both a good SWR at 432 MHz and a minimum centered above 432 MHz. This is the best way to ensure good wet weather performance. The match bandwidth on the 36-element model is actually better than on the 32. The driven element match on the 36-element Yagi also was relatively insensitive to the balun length — another good sign. The driven element for the 36-element Yagi is outlined in **Figure 10**.

Stacking the 36-element Yagi

At a 12-wavelength boom length a good Yagi will have a nearly symmetrical pattern. You can see from the calculated pattern in **Figure 11** how the H plane is starting to show nulls at 90 degrees in the pattern, similar to the E plane. The −3 dB beamwidth is still slightly wider in the H plane, even at this long boom length. This indicates that optimum spacings will be close but not quite equal in both planes.

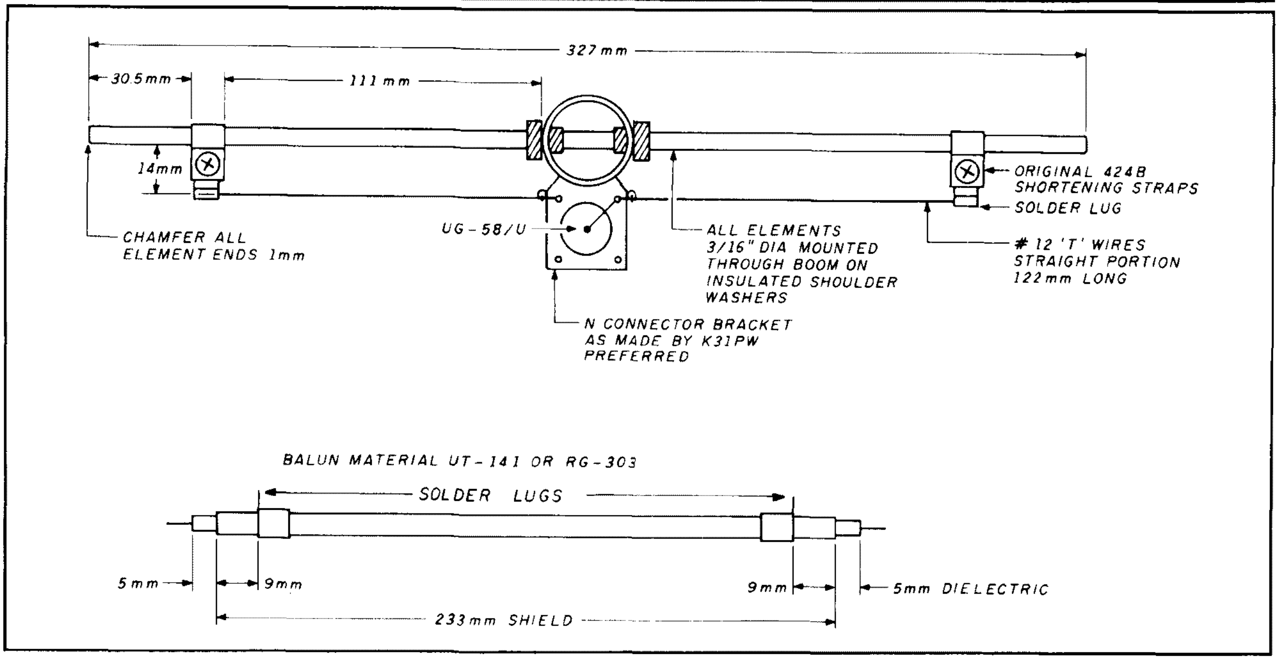
The optimum spacings for the 36-element Yagi are 87" in the E plane and 85" in the H plane. At these spacings the theoretical stacking gain in each plane is 2.9 dB.

Performance of the 36-element Yagi

The calculated pattern for the 36-element Yagi (**Figure 11**) is quite similar to the 32-element Mark 4 Yagi. The sidelobe structure is almost identical. The main lobe E and H plane beamwidths are about 1 degree narrower than the 32-element Yagi at 18 × 18.5 degrees.

Measured gain of the 36-element Yagi is approximately

FIGURE 10



Detail of the driven element of the 36-element Yagi using the no. 12 T wire match. Total boom length is 27′ 4-1/8″.

0.6 dB higher than the 32-element Mark 4 Yagi at 18.3 dBd or 20.5 dBi. Array temperature is even better than the shorter Yagis at a calculated 24K. Measurements indicate an array temperature under 30K.

Of course, on-the-air performance is what counts. WA9FWD reported a significant improvement when he upgraded from four of the 32-element Mark 2 Yagis to four of the 36-element model.

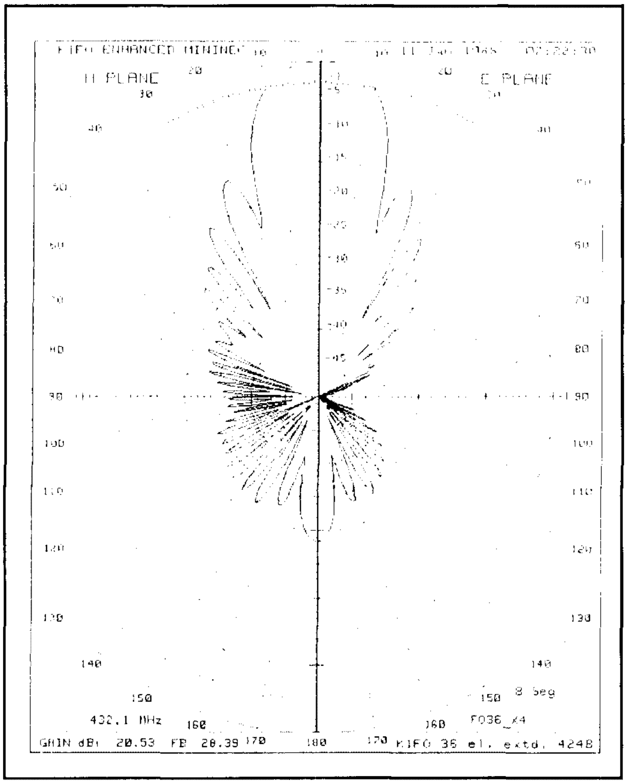
NC1I and I recently rebuilt our portable EME array to use four of the new 36-element models. The old array was 4 × 32 element Mark 2 Yagi. The new array seems to follow the predicted improvements. Measured sun noise is up 1.5 dB from the best we measured with the old array. The new array uses the same phasing lines, power divider, and preamp as the old one. The sun noise improvement is in the expected range. Gain of the 36-element Yagi is 0.8 dB higher than the 32-element Mark 2. Signal-to-noise improvement due to noise pickup and resistive losses is calculated to be over 0.5 dB. The sum, 1.3 dB, is close to the measured 1.5-dB improvement.

We first tested the new array at W1NY during the January VHF contest. We made a total of 15 EME QSOs in only 5 hours of EME operation, all with a bad antenna relay! After the contest we fixed the relay and activated the array the following weekend. We had 16 hours of EME operation spaced over the two weekends. We made 34 EME QSOs with 26 different stations, all on random. Echoes were noticeably better with the new array.

Conclusion

A top performing 432-MHz Yagi must have a proper balance of several desirable characteristics:

FIGURE 11



Calculated E and H plane patterns for the K1FO 36-element Mark 4 Yagi.

- High forward gain for the boom length.
- Excellent sidelobe structure.
- Good gain bandwidth.
- Good driven element SWR bandwidth.
- Low resistive losses.

Once you've defined these electrical traits, you must contruct your Yagi so that it will not only work in the real world, but stay up and retain that performance for many years. The K1FO 32 and 36-element Yagis have an excellent balance of these design goals, especially when you consider that they can be made easily from an existing commercial Yagi and its spare parts.

The 4-element (41" long) Yagi extension appears to be worth the effort. During initial operation with the 36-element Yagi arrays, it seemed we finally had an array that was better than a 4-Yagi array was supposed to be. As any given Yagi design is extended, its driven element impedance and rear lobe structure oscillate up and down. At a length of 27-1/2', the pattern and driven element are in optimal combination. If you plan to build a long 432-MHz Yagi from scratch, I suggest that you take a serious look at the 36-element model.

The results of the computer analysis suggest that the design could be extended still further with good results. But keep in mind that the boom would have to be extended by more than the same percent of boom change when going from 32 to 36 elements for another 0.5-dB gain. You'd need to add at least five more elements, possibly six, to see an equivalent improvement. This would make the boom almost 32 feet long. Since the 36-element Yagi weighs over 12 pounds and has a wind area of over 3 square feet, an even longer Yagi may quickly become unmanageable. A very long object also develops quite a momentum when it's moved. This added inertia requires a large increase in the mechanical strength of the array's stacking frame.

Acknowledgment

I'd like to thank Rainer Bertelsmeier, DJ9BV, for his NEC analysis and array temperature calculations of my Yagi designs hr

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1. Steve Powlishen, K1FO, "High Performance Yagis for 432 MHz," *Ham Radio*, July 1987, page 8.
2. Steve Powlishen, K1FO, "An Optimum Design for 432 MHz Yagis, Part 1," *QST*, December 1987, page 20.

MARCH WINNERS

Congratulations to George Gorsline, VE3FIU, our March sweeps winner and Rick Littlefield, K1BQT, author of March's most popular WEEKENDER — "Solo-16 Acoustic CW Speaker." Both will receive a copy of *The Radio Handbook* by Bill Orr, W6SAI.

Our WEEKENDER sweepstakes ends with the April issue. You still have a chance to send your April evaluation cards and win. The winners of the April sweeps will be announced in the June issue of *Ham Radio*.

Thanks to all of you who sent in your cards. Your comments have been invaluable to us!

Terry Northup, KA1STC

CONVERTER TUNES 4 TO 18 MHz WITH NO BANDSWITCH

By Jack Najork, W5FG, 723 Flamingo, Duncanville, Texas 75116

If you buy a new SSB rig today, chances are it includes a "general coverage" receiver that tunes from 100 kHz to 30 MHz. This range includes all the international short-wave bands and many other radio services — lots of interesting listening!

Those of us with older rigs don't have this feature. If we want to eavesdrop on these frequencies we can trade in our rigs, invest several hundred dollars (or more) in a general coverage receiver, or dig into the junkbox and create some form of compromise. My junkbox is much larger than my bank account (thanks to Dallas' famous monthly electronic sidewalk sale), so I chose the compromise approach and built a converter.

My converter covers 4 to 18 MHz in two bands: 4 to 11 MHz and 11 to 18 MHz. This span includes most of the popular short-wave bands as shown in **Table 1**. To use this converter your SSB receiver needs only to tune to 3.5 MHz, and be able to receive in the AM mode (since most broadcasters still use this form of modulation).

How it works

If you look at **Figure 1**, you'll see that the unit consists of RF amplifier Q1, local oscillator Q2, and mixer Q3. The two bands are covered without a bandswitch by using an IF of 3.5 MHz. By selecting the appropriate oscillator frequency range, you can tune this range above or below the desired incoming signal. A bit of math is all you need to understand this approach.

The oscillator range is 7.5 to 14.5 MHz. Incoming signals from 4 to 11 MHz are mixed with the oscillator to produce the 3.5 MHz IF. Signals from 11 to 18 MHz mixed with the oscillator will also produce an IF of 3.5 MHz. All that remains is to make sure you can separate the two incoming signals. Because at any one oscillator frequency the two incoming signals are 7 MHz apart, this isn't a great problem.

How does this converter compare with a new general coverage receiver? First of all, it doesn't have the same extensive frequency coverage. Secondly, the tuning rate is coarser (comparatively speaking). Each band covers 7 MHz, so the kilohertz zip by at an astounding rate as you tune. Tune very slowly and use your SSB receiver for fine tuning. On the plus side, the converter's sensitivity is excellent — 10 feet of antenna will tune in the world! And...you've saved lots of money. Despite its limitations, the converter fits the bill for casual short-wave listening.

Circuit details

RF amplifier input C1-L1 comprises a high-Q, lightly loaded, tuned circuit. This is essential for good band separation. A tapped toroid coil, along with light coupling to Q1 and loose antenna coupling, help keep the Q high. (If you don't have a suitable toroid, I've included specs for a solenoid-type substitute.) Space it at least 1 inch from metal surfaces on all sides to maintain high Q. C1 is a junkbox broadcast variable, with sections in parallel for a capacity range of 15 to 500 pF. This tunes the 4 to 18 MHz span without bandswitching.

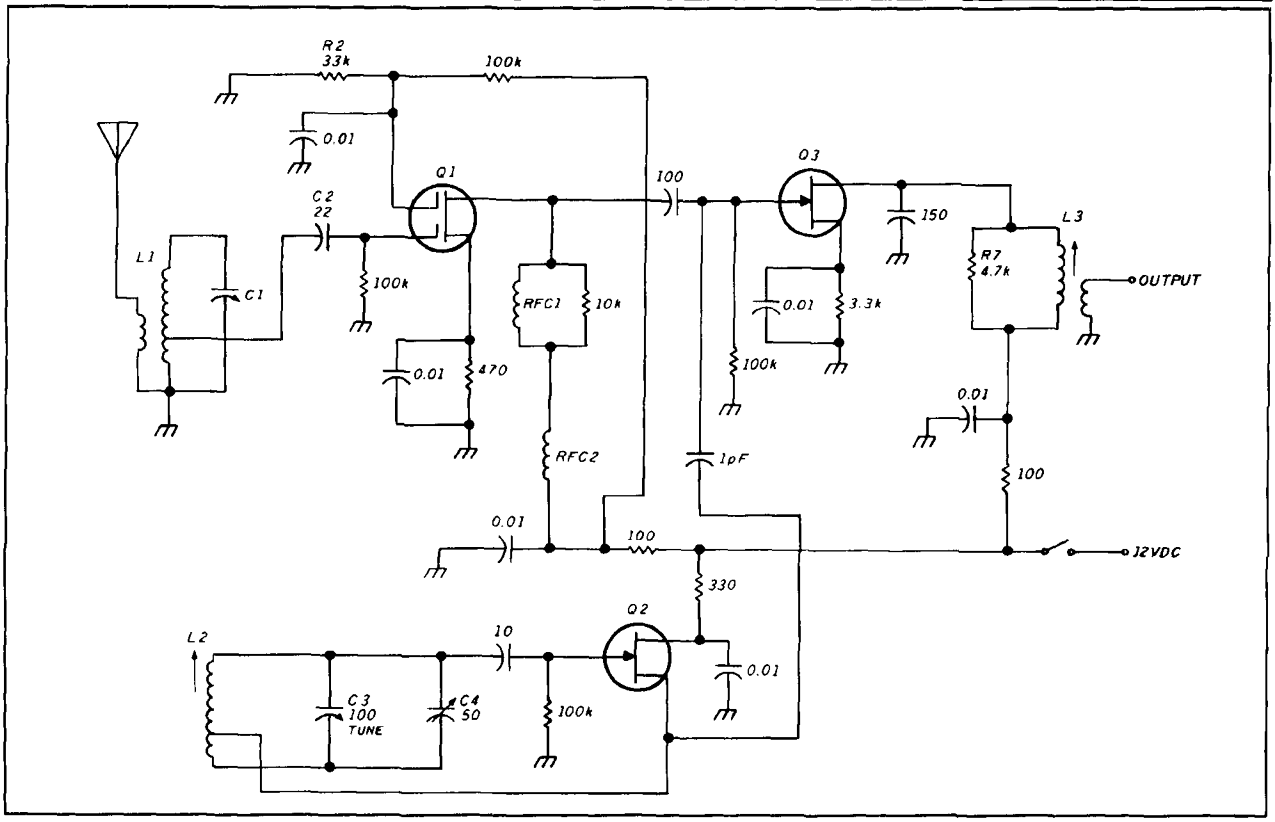
Most SSB receivers have excellent sensitivity at 3.5 MHz, so the converter doesn't need high gain. Including an RF stage lets you use a small, indoor antenna (unless you live in a shielded building). This, in turn, aids front end selectivity and avoids possible overload. RFC1 in the drain of Q1 peaks up gain at the higher frequencies.

TABLE 1

International short-wave broadcast bands.

5.95 — 6.2 MHz	49 meters
7.10 — 7.5 MHz	41 meters
9.50 — 9.98 MHz	31 meters
11.70 — 12.08 MHz	25 meters
15.10 — 15.45 MHz	19 meters
17.70 — 17.90 MHz	16 meters
21.45 — 21.95 MHz	21 meters

FIGURE 1



Schematic diagram.

Q2 is a conventional FET oscillator. C3 is another junkbox item, salvaged from an AM/FM radio. Combining the BC oscillator section (85 pF) with one FM section (20 pF) gave me the capacity spread I wanted. You can use higher capacities (like 125 or 150 pF) here, but you'll have to juggle the values of C4 and L2 to achieve the desired tuning range of 7.5 to 14.5 MHz.

Mixer Q3 is also conventional. R7, the 4.7-k resistor across the IF output coil, lowers the drain impedance to decrease possible overload. It also lowers the output circuit Q, so you can use your SSB receiver to fine tune signals 50 kHz or more on either side of 3.5 MHz.

Tune-up

Start by getting the oscillator to tune from 7.5 to 14.5 MHz. It helps to use a grid-dip meter. Next, check the C1-L1 combination for coverage with a grid dipper *before* wiring it into the circuit. If your C1 minimum capacity is too large, you won't get complete 4 to 18-MHz coverage. Some math helps here. First, determine the ratio of frequency coverage: $18 \div 4 = 4.5{:}1$. The capacity ratio needed to cover this range is equal to the frequency ratio squared. Consequently, your capacity ratio should be 4.5^2 or 20.25:1. To determine the required minimum capacity, divide the 500-pF capacitor by 20.25; you'll get 24.7 pF. Because a little overlap is good, try to reduce this minimum further — say to 15 pF. This is about the best you can do with such a large capacitor. Many BC tuning capacitors have built-in mica trimmers. Remove these, or you may never reach the minimum. Your connecting leads to C1-L1 should be short and dressed away from the chassis to prevent additional stray capacitance. (Connecting Q1 adds a few pF.) Attach C2 as close as you can to the tap on L1.

With everything wired and the smoke test passed, you should hear a definite noise peak on your 3.5-MHz receiver when you tune the IF output coil of the converter with the power on. With a short antenna on the converter, tuning C1 *slowly* should produce two noise peaks. If you get whistles and birdies when tuning C1, the RF stage is oscillating. Make sure the C1-L1 combination and wiring are well isolated from the drain circuit of Q1. If Q1 is unusually "hot," reducing the value of R2 to 22 k or 15 k will generally tame the oscillations.

PARTS LIST

PARTS LIST

C1	15—500 pF variable.
C2	22 pF.
C3	100 pF variable.
C4	50 pF variable.
L1	26 turns no. 24 enameled on T.50-2 toroid or 10 turns no. 20 enameled spaced 3/4" on 1-1/4" form. (35-mm film container.) L = approximately 3.2 μH. Link: 2 turns. L1 center tapped.
L2	22 turns no. 24 enameled on 3/8" slug-tuned form, tap 6 turns from ground. L = 3μH.
L3	40 turns no. 32 enameled on 1/4" slug-tuned form. L = 15 μH. Link: 5 turns.
Q1	Dual-gate FET, 40673 or similar.
Q2,Q3	JFET, MPF 102 or similar.
RFC1	50 turns scramble wound on 1/4-watt, 10-k resistor. No. 32 enameled.
RFC2	1 mH RFC.

Because of the large frequency spread of each band, you'll find a good-quality slow-tuning vernier dial is essential for oscillator tuning. It's best to do your dial calibration with a signal generator. You need to calibrate only one band; the second is automatically 7 MHz different from the first.

You should also do a rough calibration of C1 so you'll know which band you're tuning. To check the quality (selectivity) of your C1-L1 combination, tune to the 7 to 14-MHz calibration mark. Tuning C1 slowly from minimum capacity should first bring in 20-meter CW; as C1 is increased, 20 should drop out and 40-meter CW should appear. The C1 tuning peak should be very sharp and you can judge it best by watching your receiver's S-meter.

As I mentioned earlier, you should use a short antenna to minimize the possibility of overloading and decreased front end selectivity.

All parts can be obtained from Radiokit, Box 973, Pelham, NH 03076. Ed.

THE FOLD WIRE FED

TOP-LOADED GROUNDED VERTICAL

By Walter J. Schulz, Jr., K3OQF, 15225 Wayside Road, Philadelphia, Pennsylvania 19116

It's common practice to use the folded wire tapped to a grounded tower to feed the tower as a vertical radiator with top-loaded Yagi or quad antennas. You can use these installations as top-loaded verticals on 40, 75, and 160 meters. John True, W4OQ, did an empirical study of this type of system and wrote about the results in *Ham Radio* Magazine.[1,2] After reading his study, I decided that I needed to be able to design the system on paper — independent of sets of interpolative electrical measurements. I had to answer a number of questions to achieve my design goals; there were two that concerned me most. What's the actual grounded tower electrical height with Yagi or quad antennas, and what's the impedance to be expected at a tap point on the tower? To resolve these questions, I looked at the physical aspects in a different way. I assumed that the whole antenna system was a transmission line UHF tank circuit (**Figure 1**).

It's well known that the quarter-wave transmission line will act as an impedance transformer and match two different impedances. This phenomenon is an advantage at ultrahigh frequencies where lump-constant components of capacitance and inductance are too large to be used in a tank circuit. A quarter-wave transmission line can be used as a tank circuit;[3] it will display a very high quality factor (Q). Keep the transmission line length at a quarter wave and place a tap along the length for matching impedances if you wish. This tap will transform impedances between the tap point and an active device like a tube or transistor.

Sometimes it's desirable to have a shorter length of transmission line. You can reduce the length of the line by using a loading capacitance at its open end. The transmission line is shorted at one end and capacitively loaded at the other. The tap point along the transmission line will always be a pure resistance with no reactive component, as long as the line is equivalent to a quarter wave which is parallel resonant.

The transmission line tank circuit can be compared with a tower capacitively loaded by a Yagi or quad antenna. The impedance is transformed by placement of a tap along the tower. It's difficult to figure out where to place the tap on the tower or transmission line, as every Amateur location is unique. You can make a fairly accurate first approximation; this will place the tap near the optimum position on the tower for an impedance match. Once you've made your calculation, a little experimentation will show exactly where the tap should go.

Here's an example. A Rohn Model 25 tower has 90-degree electrical height on 3.8 MHz. This serves as a reference parameter for further calculations. Use the algorithim that follows to determine the tap point on the tower that gives you a 52-ohm match.

Establish the feedpoint impedance for the height and diameter of the tower using Schelkunoff's equation.[4] In this instance his equations derive shape factor as $Z_0 = 316$, and a complex feedpoint impedance as $R_r = 37.7$ ohms + j21.8 ohms. Next, find the quality factor:

$$Q = \frac{X_L}{R_r} = \frac{+j21.8\Omega}{37.7\Omega} - 0.5782 \quad \textbf{(1)}$$

Treating the tower as a transmision line, find the loop resistance:

$$R = \frac{6.28(Z_o)}{Q(\lambda)} = \frac{6.28(316)}{(0.5782)(78.96)} = 43.4635 \quad \textbf{(2)}$$

λ = 78.95 meters

$$\lambda = \frac{3\times10^8}{f} = \frac{3\times10^8}{3.8\times10^6} = 78.9475 \text{ meters} \quad \textbf{(3)}$$

Find R1 (loop resistance) value on the tower:

$$R1 = \frac{8(Z_o)^2}{R(\lambda)} = \frac{8(316^2)}{(43.4635)(78.96)} = 232.773 \quad \textbf{(4)}$$

Find the ratio of R_t to R1:

$$\alpha = \frac{R_t}{R1} = \frac{52}{232.773} = 0.2234 \quad \textbf{(5)}$$

FIGURE 1

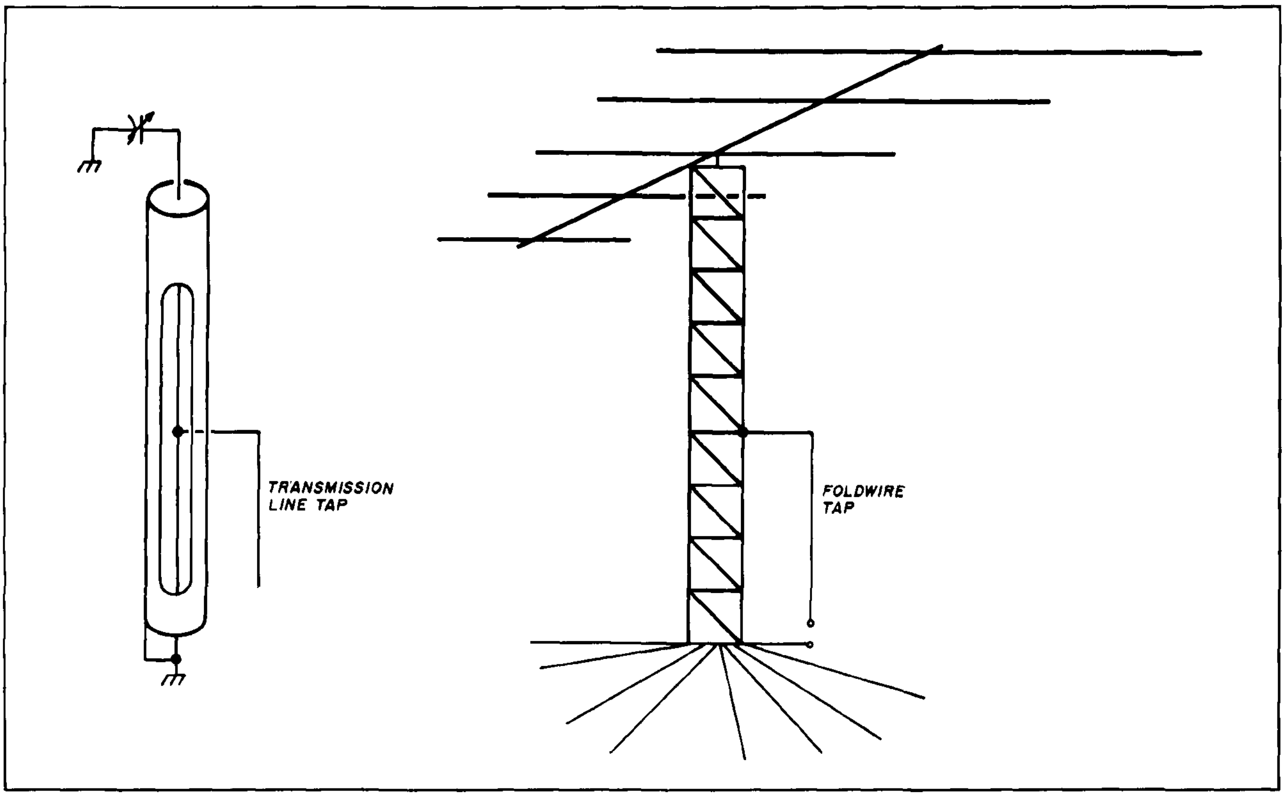


Illustration of a shunt fed tower and its electrical equivalent.

Note: R_t is the tap point impedance. In this case it's 52 ohms.

θ tap point on tower

θ *tap point* $= arc\ sin\ (\alpha\ sin^2\theta_{Gt})^{1/2}$

θ *tap point* $= arc\ sin\ [0.2234 sin^2(90)]^{1/2}$

θ *tap point* $= arc\ sin\ 0.4727$

θ *tap point* $= 28.2°$ **(6)**

Convert tap point height from degrees to feet above ground:

$$\frac{28°}{360°}(259) = 20\ feet \quad \textbf{(7)}$$

If you want to find other tap points above the tower's base and along its length, you need to know the total electrical height of the whole antenna system. Determine the tap point position on the tower length by using proportions to get the first approximation. The first approximation gives you a starting point from which to calculate tap placement on the tower. You may find you have to move the tap up or down. This adjustment, which increases or decreases resistance transformation at the tap point, is necessary for a match to the transmission line.

Electrical antenna height or line length

I'm sure you've seen how electrical antenna height differs from actual physical antenna height. Literature on the subject shows how this phenomenon has been put to use changing antenna current distribution and raising the radiation resistance. You might find it helpful to ask the following questions about an antenna structure already supporting a Yagi or quad antenna, especially if you want to fold wire feed a grounded tower as a vertical radiator.

- What is the total antenna electrical height?
- What is the equivalent electrical height represented by top loading?
- What is the proper tower tap point for shunt feeding?

Consider a Rohn Model 25 tower 55 feet high. This tower supports a TH6DXX triband Yagi which, for our purposes, can be compared to a flat top antenna with parallel wires. Assume the elements are parallel wires forming a flat top, but each is of a different length. You must average all element lengths (six in the example) to get a uniform length for use in a capacity equation by Grover.[5] You must also average each element's different spacing along the boom. After averaging these boom lengths and spacings, you're ready to use these values to find the flat-top capacitance loading.

The average element spacing is 57″; the average element length is 276″.

Find the capacitance:

$$C\ in\ pF = 7.36\frac{\ell}{F} \quad \textbf{(8)}$$

$$Q = log\frac{2h}{D} - K = log\frac{1320}{57} - 0.874 = 0.4907 \quad \textbf{(9)}$$

$$P = log\frac{4h}{dia} - K = log\frac{2640}{1} - 0.874 = 2.5476 \quad \textbf{(10)}$$

$$F = \frac{P + (n - 1)Q}{n} - K_n = \tag{11}$$

$$\frac{2.5476 + ((6 - 1)(0.4907))}{6} - 0.252 = 0.5815$$

$$C = \frac{7.36\ (23\ ft)}{0.5815} = 291\ pF \tag{12}$$

The capacitive value represented by the Yagi is 291 pF.

Find the capacitive reactance from the previous value:

$$X_c = \frac{1}{6.28\ (3.8 \times 10^6)\ (291 \times 10^{-12})} = 144\Omega \tag{13}$$

Find the shape factor for the antenna tower:

$$Z_o = 60 \ln \frac{(2h)}{(a)} - 1 = 60 \ln (2) \frac{(660'')}{(2.95'')} - 1 = 306 \tag{14}$$

Find the equivalent electrical height of the whole structure:

$$\theta H_b = \mathrm{arccotan} \frac{X_c}{Z_o} = \mathrm{arccotan} \frac{144}{306} = 65^\circ \tag{15}$$

$\theta H_a = 76^\circ$
$\theta H_b = 65^\circ$
$\theta Gt = 141^\circ$ *total height* ϵ *electrical degrees*

Finding the tap point on the tower

You know that the tap point on the reference tower structure is 28 electrical degrees above the tower's base for a tower of 90 electrical degrees in length. This means you'll use proportions to find the tap point for antenna heights other than 90 degrees. Say you want to find the tap point for an antenna height of 141 electrical degrees. Let X be the unknown value for the tap point on the tower Once you determine the tap point in electrical degrees, convert this value to feet.

$$\frac{90}{28} = \frac{141}{X} \tag{16}$$

$$3.2143 = \frac{141}{X} \tag{17}$$

$$X = \frac{141}{3.2143} = 44^\circ \tag{18}$$

Converting to feet:

$$\left(\frac{44}{360}\right)(258.9474) = 32\ feet \tag{19}$$

(See Figure 2.)

Preparing the tower for shunt feeding

One of the first things you must do when shunt feeding a grounded tower is insulate the upper portions of the tower from ground. Do this by placing egg insulators where the guy wires connect to the tower. It's usually advisable to break up the guy wires with insulators every 1/10 of a wavelength to prevent reradiation by the wires and radiation pattern distortion.

Once you've located the tap point, you can feed it in one of two ways. The first is to extend a folded wire straight out from the tap point and drop it down parallel to the tower's base. RF excitation will occur at the earth's surface. Another method (which gives slightly better bandwidth and results) is to build a cage about the same diameter as the tower, instead of using a single wire. You can hang the cage on an outrigger extending out from the tap point and running parallel to the tower down towards the ground. The cage works better than an aluminum pipe, and offers less wind resistance. It also decreases the amount of weight that's hanging off the tower.

Once the fold wire or cage is in place, there are a number of things to do before exciting the tower with RF power. To start, hang the outrigger arm at the first approximation tap point. (The arm can extend 1 to 3 feet out from the tower's side. The outrigger arm material is usually a light metal, like alumninum pipe, with a 1-inch outside diameter, that's clamped to the tower legs with U bolts.) Suspend the fold wire or cage from the first outrigger to a second one at the tower's base. Make sure the bottom outrigger has an insulator, so that the cage is insulated above the ground.

The impedance noise bridge is a valuable tool for determining the feedpoint impedance at the fold wire or cage feedpoint on the bottom outrigger. You can move the wire in towards the tower or away from it to determine which spacing gives the best impedance match, then try raising or lowering the tap point for a better match. Observe the reactance value on the bridge once you've found the tap point with the best match.

It may be a good idea to cancel out the inductive reactance before moving the tap point position, or the fold wire in and out from the tower. I've given approximate values for maximum capacitance to cancel out the inductive reactance for the following bands: 1000 pF for 160 meters, 500

FIGURE 2

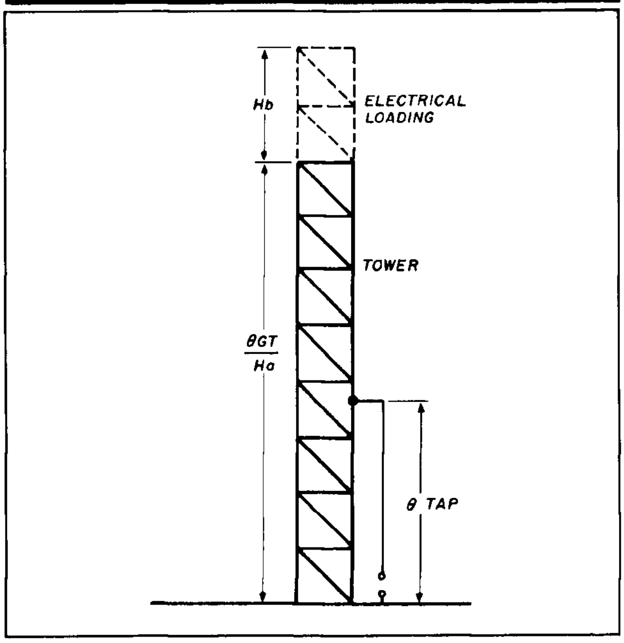
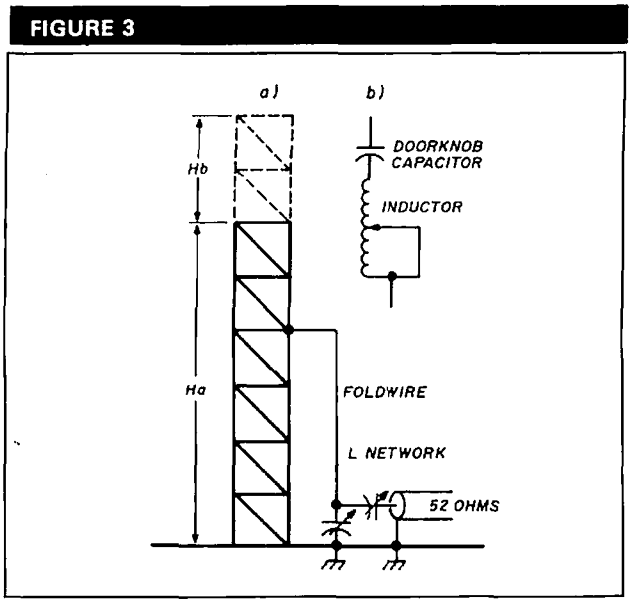


Illustration of the electrical height of the tower in degrees and the approximate placement of the tap in degrees.



Two methods of tuning out the inductive reactance at the feedpoint on a shunt-fed tower. (A) Variable capacitors are used to tune out inductive reactance. (B) Fixed capacitors are used with a series variable inductor to tune out any additional capacitance in the circuit.

pF for 80 meters, and 300 pF for 40 meters (**Figure 3A**). You can obtain these capacitance values by using a variable capacitor or a fixed capacitance (doorknob capacitor), along with a series inductance to negate the fixed capacitance not needed to cancel out the antenna inductive reactance (**Figure 3B**). When you've canceled out the reactance component, match the resistance value in the usual way. Use an L or T-network, or toroid transformer, if the feedpoint isn't an exact 52-ohm match. Remember the fold wire will always present inductive reactance and this reactance must be canceled out with capacitive reactance. By using the fold wire you eliminate the need for a loading coil, increasing radiation efficiency.

It's also *important* to remember that you should have a good ground system with many radials when shunt feeding top-loaded towers. This doesn't mean just a few long radials, but a minimum of 60 radials 1/8 wavelength long. If your ground system is inadequate, it will be hard to find the tap point placement and total system adjustment will be very difficult. The calculations are made assuming the ground system will have little loss resistance. **hr**

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3. Capitol Radio Engineering Institute, *Transmission Lines*, McGraw-Hill, Inc., 1972 edition, pages 11-23.
4. S.A. Schelkunoff, "Theory of Antennas of Arbitrary Size and Shape," Institute of Radio Engineers Proceedings, September 1941, pages 493-520.
5. Frederick W. Grover, "Methods, Formulas, and Tables for the Calculation of Antenna Capacity," Bureau of Standards, volume 22, 1927-1928, page 588.

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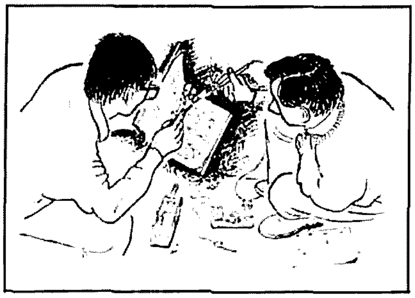
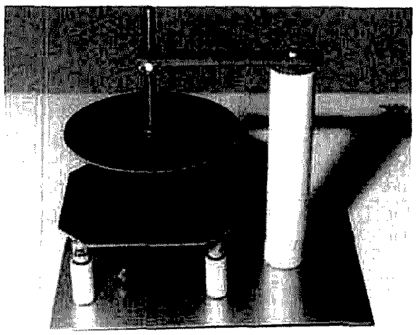
Ham Notebook



Homebrew Neutralizing Capacitor

Most of us now have transceivers with an output of 100 watts. This is ideal for driving a high-power triode amplifier. Such an amplifier isn't difficult to build and can be quite economical if you have some 250Ts, 833As, etc. stored away somewhere. Perhaps you have a ham friend who works at a broadcast station. Stations often remove tubes from service that are perfectly good for Amateur use, especially for CW. Some

PHOTO A



Example of a completed Neutralizing Capacitor.

of the other components, however, may be difficult to find or too expensive. The neutralizing capacitor need not fall into this category.

My list of materials isn't cast in concrete. Use what you have on hand and calculate the capacity range from the formula in *The ARRL Handbook*. The items specified will result in a capacity of 1 pF at 3.0″ spacing to 5.6 pF at 0.5″ spacing.

Construction

Use pc board material with copper on one or both sides. Make the top plate using a circle cutter. Cut the bottom plate 4″ square and then trim off the corners. Round the edges with a file and polish them with fine sandpaper or crocus cloth. You can mount the bottom plate on just one center insulator, but I used four to make it sturdier. Countersink the top plate center hole and fasten on the 3″ brass bolt with a lock washer and nut. Solder the bolt head to the pc board copper. This is the only tricky part of the entire project. Be careful not to make the countersink too deep. If you do, there will be a gap between the bolt head and the copper foil. It will be very difficult (I might even say nearly impossible) to bridge that gap with solder. Saw a slot in the other end of the 3″ bolt for screwdriver adjustment.

PARTS LIST

1 - 4" diameter piece of pc board
1 - 4" square piece of pc board
1 - 1/4-20 3" long flat-head brass bolt
3 - 1/4-20 brass nuts
1 - 1/4" lock washer
1 - 3/16"x3/8"x4" brass bar
1 - 1"x5" ceramic insulator
4 - 1/2"x1.5" ceramic insulators
Fiber washers and brass machine screws for the insulators

The support for the top plate is a piece of brass 1/8″×5/16″×4″. If you use hollow brass, solder on a 1/4-20 brass nut after you drill a clearance hole for the 3″ brass bolt. If the brass is solid, you can drill and tap it for the 3″ brass bolt. You also need to countersink the four flat-head machine screws holding the bottom plate flush with the pc board copper.

Ken Leiner, N4LC

Adding 10 MHz to the HyGain HyTower

Although it's an older antenna, the HyGain HyTower is still in use in the United States, Canada, and around the world. The HyTower is basically a quarter-wave vertical. The antenna incorporates various tuning stubs; these decouple it for bands other than 40 and 80 meters. For 160 meters, the antenna uses a base-loading coil.

I've operated with the HyTower at W5UOJ for almost 16 years, and it was *used* when I got it! It's never failed on 160, 80, or 40 meters. Because I have beams for 20, 15, 10, etc., I never installed the stubs for 20, 15, and 10 meters on this particular antenna.

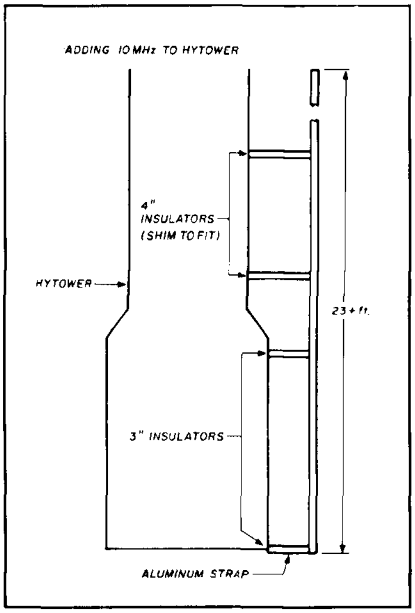
After the 30-meter band (10.100 to 10.150 MHz) opened, I tried the HyTower with an old Collins S-Line. The SWR was relatively low and it worked after a fashion. Because there's a coil for 160 installed in the 80-meter line (mostly shorted out for 80 meters), I could vary the SWR by moving the tap on the coil. Apparently the antenna was working as a three-quarter wavelength vertical.

I didn't get very good signal reports with the antenna this way. It worked, but...! I decided to add a matching section for the 30-meter band.

I garnered several pieces of aluminum from the antenna graveyard and pieced them together. Most of my matching section addition was 1-inch tubing. I inserted a shorter piece of 7/8-inch tubing into the end for tuning.

I started with a total length of just over 23 feet, and tuned the antenna for the best SWR by telescoping the 7/8-inch section up and down inside the 1-inch section. I installed two 3-inch stand-off insulators along the first section of tower and two 4-inch insulators on the second section (see **Figure 1** *for details*). *I shimmed them with small* sections of plastic from margarine tubs to bring the 23+ foot section vertical. This took care of almost 16 feet; I left the remaining 7 feet freestanding.

FIGURE 1



Mechanical details for attaching the 23-foot matching stub to the Hygain Hytower.

Next I strapped the bottom of the newly added stub to the bottom of the tower leg with a scrap of aluminum. (You could probably use heavy wire.) Then I adjusted the antenna for minimum SWR. Because my antenna is mounted next to the house, I could make these adjustments with the stub mounted permanently. If your HyTower is mounted away from a building, put up the lowest and highest insulators and make the tuning adjustments by moving the antenna stub up and down. You can mount the stub permanently when the SWR is the lowest.

My stub was just short of 23 feet; the actual length of yours may differ. Because the antenna is mounted next to the house, and since the stubs for 20, 15, and 10 meters aren't installed on it, the final stub length could vary. Always check the SWR before finalizing your work!

The stub adds a third antenna in parallel with the existing 80 and 40-meter sections. With a good ground system this antenna can easily work the world. Stateside contacts are also much easier to make.

I spent less than an hour on this modification, and the time was well spent. It cost me nothing because I had all the materials on hand. Even if you have to purchase everything, it should cost less than $20 — and probably less than $10. Of course, the modified HyTower isn't a beam. But considering that many stations working the 30-meter band are using dipoles and even long wires, it does make for a better-than-average antenna! See you on 30!

Glen Zook, W5UOJ

The N5NBU "Nice but Ugly" $1.29 Antenna

Living in an apartment presents special challenges for Amateur Radio operators. Limited space and landlord rules pose difficulties, particularly when it comes to antennas. When I was told that my ground plane had to come off the balcony, I decided enough was enough and the "Nice but Ugly" $1.29 antenna was born. (See **Figure 1**.)

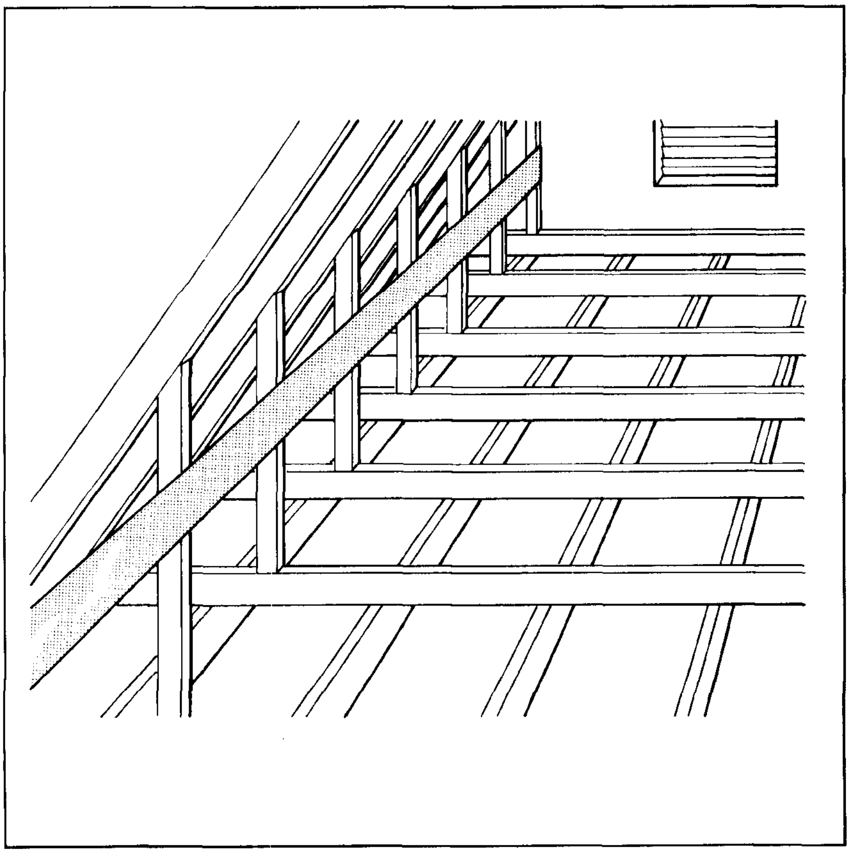
My requirements were simple. I needed to put up an antenna that was as effective as possible within the space available. Then the XYL added another constraint: "Try not to spend any money on it."

I tried and discarded gems like "The Bedroom Wall Quad" (two square wire loops on opposite walls of the bedroom) and "The Guillotine" (a long wire strung throughout the place, which was a real adventure in the dark!).

Then, by sheerest chance, I saw some light at the end of the tunnel — or rather, in the ceiling. While replacing a light bulb in the closet, I noticed an access panel in the ceiling. I lifted it up and, lo and behold, space! A whole attic just waiting for an antenna installation! I immediately sat down and started contemplating antenna designs.

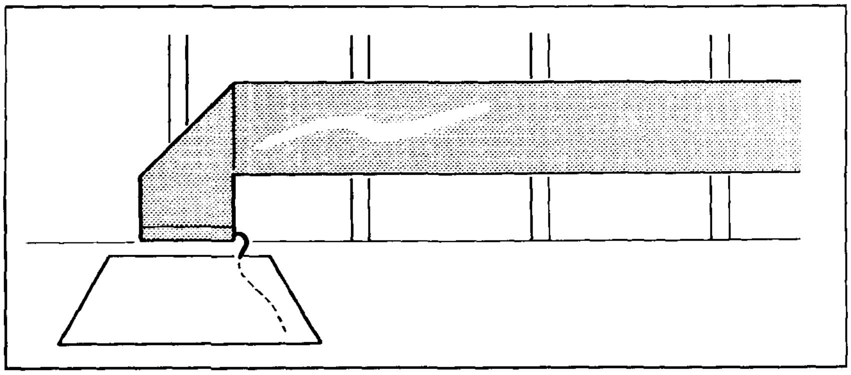
I made a couple of trips into the attic with measuring tape in hand and my plan began to take shape. Because I had severe budgetary restrictions, the antenna had to be simple and built with materials I had around the house. What's cheap, long, and conductive...?

FIGURE 1



Installed view.

FIGURE 2



End-feed view.

Eureka! Aluminum foil! Because the antenna would be installed in the attic there wouldn't be any wind loading, and there were convenient vertical supports (roof trusses) running the length of the attic. I went into the kitchen, got out the roll of foil, and measured off 66 feet (the length of my attic, and two full waves at 10 meters — how convenient) plus a little bit for anchoring purposes. I decided an end-fed antenna would be perfect as it involved just a single wire to my tuner.

After measuring out the foil and locating my box of tacks, I once again climbed into the attic. Starting at the far end, I rolled and flattened about a foot of foil for a good strong anchor, held it vertical, and thumbtacked it to the support on the far end of the attic. Working my way back to the access hatch, I unrolled the foil and tacked it to every fourth vertical. They're spaced about 18 inches apart. I continued this rather tedious process (tedious because the foil is quite delicate) until I came to the access panel. Then I folded the foil over to bring it down to the edge of the access. To connect the antenna to the tuner, I scraped off about 2 feet of insulation from an 18-foot piece of no. 16 enameled wire, then soldered it (sort of) to a piece of foil about a foot long using "the bigger the blob, the better the job" method. I rolled this up into the end of the antenna, flattened it, tacked it down to the edge of the access, and connected the wire to my MFJ Deluxe Versa Tuner II. (See **Figure 2**.)

Now it was time for the acid test. I tuned the transmitter up into the dummy load, switched to the antenna, and heard the (new and thrilling) sounds of DX stations. After finding a clear spot on 10 meters to finish my tune-up, I called CQ and immediately got my own mini-pileup. The SWR meter said I was matched up with a 1:1 ratio, and the stations I was talking to were giving me S9+20 reports. It was the same story with CW on 15 and 40 meters. On 80 meters I have a problem with RF "bites," but a good ground should cure that problem. I've greatly alleviated and almost eliminated my TVI. My primary problem was fundamental overload. Now just turning the rabbit ears parallel with the plane of the antenna greatly reduces and just about gets rid of TVI on channel 2 (my problem channel).

I hope you'll try my Nice but Ugly antenna. Just remember basic safety precautions regarding power lines, etc. and you'll have a safe and trouble-free installation.

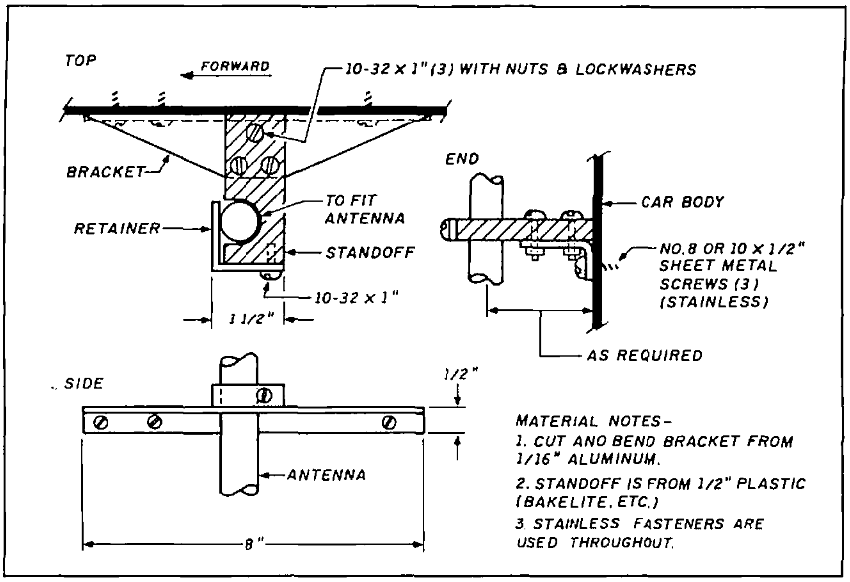
Now, I wonder if I can do something with these tin cans...

Don Lane, N5NBU

Mobile Antenna Anti-rotate Device

Mounting your low-band mobile antenna on your bumper is the easiest method — mechanically. It's also best for performance. But this mount is impossible on many station wagons and "three door" cars. Side mounts are apt to rotate, unless they include a rugged anti-rotate device. I used a standard ball mount, which rotated even when minimal force was applied. My solution for this rotation problem is shown in **Figure 1**.

FIGURE 1



Anti-rotate bracket for side-mounted mobile antennas.

I attached the aluminum bracket to my car with stainless steel sheet metal screws available from most hardware stores. My installation fits two different diameter antennas, so I cut the hole in the standoff for the larger one. I bushed out the smaller antenna with a 4-inch length of clear plastic hose, also from the hardware store. I split it lengthwise and attached it with a hose clamp. I added the L-shaped retainer at the front of the mount to prevent rotation in the forward direction (less likely). You'll need to vary my dimensions to fit your car and antenna(s).

This device has stood the test of several thousand miles and many QSOs. Thanks to Bob, W1KSK, for his original suggestion.

George Wilson, W1OLP

Elmer's Notebook

Tom McMullen, W1SL

OSCILLATORS

Oscillators have been a part of radio since the use of spark transmitters. The waves spark transmitters generated weren't the clean waveforms available with modern circuitry, but they *were* radio waves. They weren't self-sustaining; they reached an energy peak when first started, and each successive peak was weaker (because of circuit losses) until the wave died out completely. These were known as "damped" waves.

The vacuum tube saved the day. It allowed for the addition of enough power to the circuit to overcome the losses and maintain the waveform as long as voltage was applied. Vacuum tubes were standard in many types of oscillator circuits for many years, and are still the mainstay when you need more than a few watts of RF power to drive the next stage.

Transistors are prevalent in modern equipment. These small, quiet, relatively cool devices perform well as oscillators from audio frequencies up into the microwave region. But whether the oscillator is a tube or transistor, the thing that makes it perform is feedback.

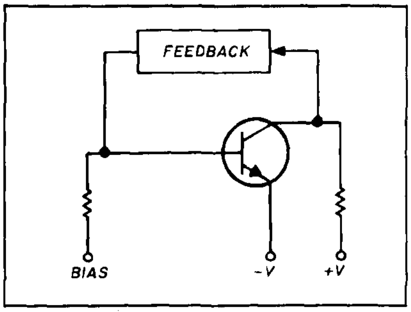
Feedback — the vital ingredient

Basically, an oscillator is an amplifier with some of its output signal fed back to the input in a proper phase relationship. If the waveform phase adds to the input waveform, the circuit will oscillate; if it tends to cancel the input waveform, it won't.

Feedback that tends to cancel the input waveform is called negative feedback, and this very characteristic has been used in many circuits to improve their operation. For example, negative feedback is used in high-quality audio amplifiers to reduce distortion and prevent overload. In RF circuits, negative feedback is called *neutralization* and is used to *prevent* oscillation. Circuit designers can use phase-shifting networks and filters to tailor feedback for almost any situation.

Here's an example of how feedback gets things started. **Figure 1** shows a simple transistor circuit with a black box called "feedback" connected between the output (collector) and input (base) of a transistor. (Don't worry about what's in the box right now.)

FIGURE 1



An oscillator is an amplifier with controlled feedback. Here, the "black-box" between the collector and base provides the voltage feedback and phase shift needed to keep oscillation going.

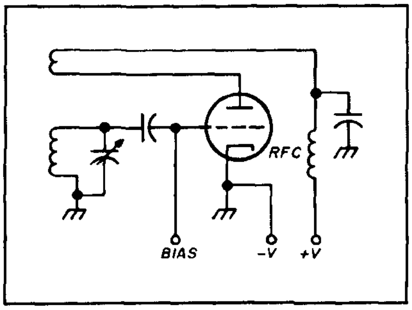
Let's say that the AC voltage on the collector reaches 10 volts, and that the transistor provides a voltage gain of 20 (that's simple voltage gain, not decibels). All the black box needs to do is supply 0.05 volts to the base. The transistor will amplify that by 20, and maintain the required 10 volts on the collector. A good design adds an extra fraction of a volt to the feedback to take transistor aging, low supply voltage, and other troubles into account — just to be safe. The phase of the voltage must be "aiding," that is, near 0 or 360 degrees. But applying too much feedback voltage isn't good. It can overdrive the transistor, causing the waveform to distort and create harmonics. The transistor will also draw more current than needed, and may overheat.

What's in the box?

You can obtain feedback in many ways, and electronic handbooks often show a dozen or more types of oscillators. **Figure 2** represents an old standby used for many years in various commercial and Amateur applications. It's a tube circuit with a small coil in the plate circuit located near the windings connected to the grid. This was once called a "tickler" coil.

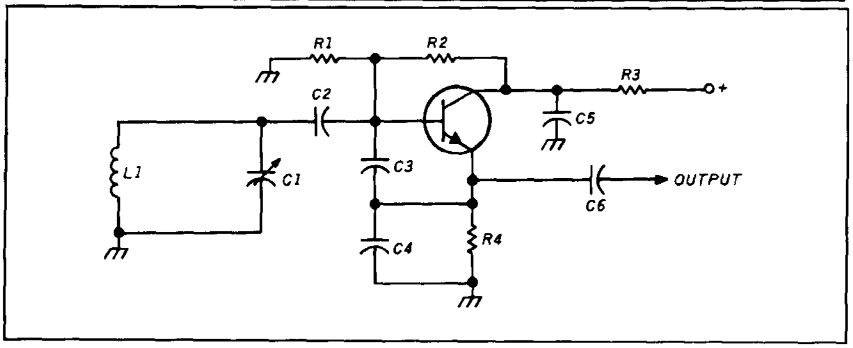
The amount of feedback was adjusted by moving the coil closer to or further from the input circuit. The phase was determined by having the winding start and finish properly connected in the plate circuit. The old rule of thumb was: "If it doesn't oscillate, reverse the feedback windings." Some oscillators in early receivers had a feedback coil that could be rotated, letting you fine tune the strength of oscillation. (A few of these oscillators were known as "regenerative receivers.") This isn't a very elegant method of

FIGURE 2



An early "brute force" type of feedback used a plate coil located so that its magnetic field was coupled to the grid tuned circuit.

FIGURE 3



A modern circuit uses feedback from the emitter to base of a transistor via C3. C3 and C4 form a voltage divider; R1 and R2 provide base bias. The collector is bypassed to ground for RF, and output is taken from the emitter via C6.

providing feedback, but it works. Because physical vibration and temperature cause problems in oscillators, it follows that a circuit with two coils prone to vibration and heat will be more unstable than a circuit with only one

Figure 3 takes another approach to feedback. In a more modern transistorized circuit, a capacitive voltage divider couples some of the energy from the emitter circuit to the base circuit. The value of the capacitors from base to emitter and emitter to ground determines the strength of the feedback signal. The resonance of the tuned circuit sets the frequency of oscillation. The collector circuit is bypassed for RF, which completes the signal path back to the emitter.

You may wonder how the oscillation gets started in the first place. When power is first applied to an oscillator, the rush of current through the transistor (or tube) and the tuned circuit starts the "store energy/release energy" cycle. This cycle peaks at the circuit's resonant frequency. The action creates a small signal at the base (or grid, in a tube). Because the circuit is an amplifier, this small signal is amplified. A portion of it is then fed back to the input to further enhance the oscillation and be amplified again, and so it goes. The whole procedure requires only a few cycles to reach full strength.

Audio oscillators get started in a similar fashion, except that most depend upon a resistance/capacitance phase-shift network to determine the frequency of oscillation. The voltage change across the output load resistor creates a starting signal, which is fed back, amplified, and so on. It's possible to use a transformer to obtain inductively coupled feedback for an audio oscillator, but why lug the heavy iron around if you can use something else?

Back to the RF circuits. **Figure 4** shows two oscillators that use crystals as their frequency-determining element. In **Figure 4A**, the crystal is connected from base to ground. It serves the same purpose as the tuned circuit in **Figure 3**, by forming a parallel-resonant circuit at the base. In **Figure 4B**, the crystal is a series-resonant type and provides feedback at the crystal frequency directly from collector to base.

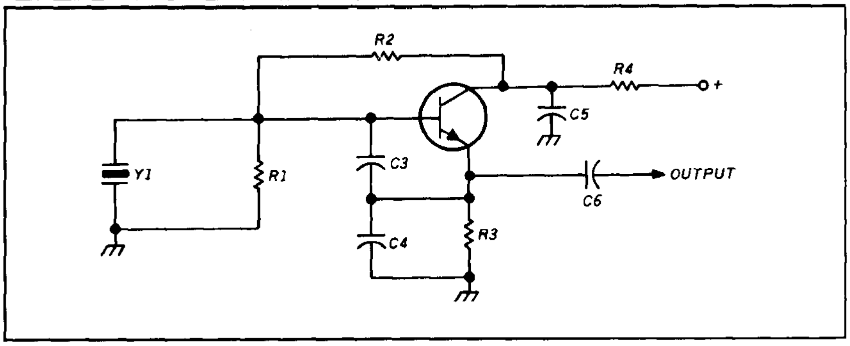
There are many variations of these circuits; some have names associated with their inventors. **Figures 3** and **4A**, for example, are versions of what is often called a Colpitts oscillator; **Figure 4B** is a Pierce oscillator.

In **Figure 5**, you'll notice one of those voltage-variable capacitors I explained in last month's column. It looks like a cross between a capacitor and a diode, and changes its capacitance in proportion to the DC voltage applied. In the circuits used last month, I varied the negative (-) voltage applied to the diode to change the capacitance. Instead of using two supplies, one negative and one positive, this circuit simply reverses the diode and varies the positive (+) voltage to tune the circuit by means of R1.

What makes an oscillator unstable?

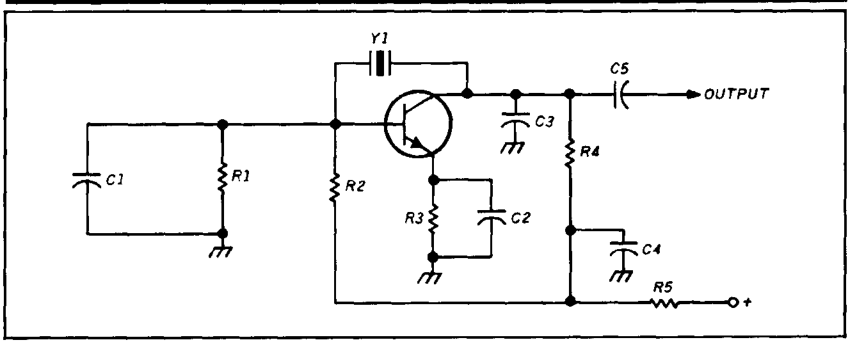
Frequency stability is one of the

FIGURE 4A



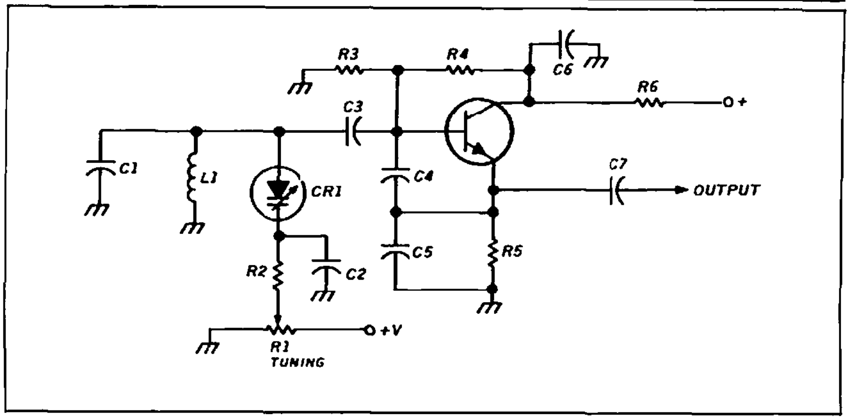
A Colpitts-type crystal oscillator.

FIGURE 4B



A Pierce-derivative crystal oscillator. This crystal provides feedback at its natural frequency. C1 and C3 are small-value capacitors used to stabilize the amount of feedback, preventing overdrive to the transistor and crystal.

FIGURE 5



A VFO circuit using a voltage-variable capacitor as the tuning element. This can also be called a voltage-controlled oscillator (VCO).

prime goals in designing and building an RF oscillator of any type. Mechanical stability is a close second.

It's almost impossible to design an oscillator that ignores temperature changes, but there are tricks that help you come close. Because many components cause frequency changes when the circuit gets warmer, it's possible to use temperature-compensating capacitors to provide an opposing characteristic when they warm up. If you select the proper values, the result will be an almost temperature-stable oscillator.

Of course, keeping the entire circuit away from other elements that produce heat makes your task much easier Power supply rectifiers, transformers, and sometimes filter capacitors plus power-amplifier stages all heat up their surroundings, and you should avoid them when placing an oscillator on a chassis. Ventilate the enclosure to let heat escape or, if that isn't possible, use good heat-sink material to get the heat out of the box and into the free air where it won't harm anything. Good design also calls for keeping the current drawn by the oscillator device as low as possible. Current passing through resistors (and tubes or transistors) produces heat, so the less heat produced, the less heat there is to be dissipated.

Mechanical instability is evident in two forms. One form is called microphonics. If you tap on the enclosure and hear a "boing" when listening to the oscillator in a receiver, you have microphonics. The other form is a noise or a jump in frequency when you tune the oscillator. The microphonic type is caused by something moving in the RF field of the oscillator-tuned circuit. It may be the walls of the enclosure, a nearby component with long leads, or even the tuned circuit components (loose windings and air-variable capacitors are prime suspects). The cure is to mount everything very rigidly, and allow space between the coil and other components so that the RF field doesn't intercept a loose or vibrating part. Heavy or rigid oscillator-enclosure walls and chassis help too.

Noise and frequency jumps are usually caused by dirty contacts in the variable capacitor of the tuned circuit. Even the voltage-variable capacitor isn't immune, because the potentiometer that changes the voltage can become noisy just as volume controls do in an audio circuit. Clean contacts are the answer for the variable capacitor There are chemical solutions that you can use to cure the problem in both capacitors and variable resistors. If all else fails, replace the noisy part with a new one. It's worth noting that even oscillators that vary the inductance rather than the capacitance are not immune to this problem, because anything that is in the RF field of the coil can induce noise (and temperature instability) into the circuit. hr

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(See "Publisher's Log," April, 1984, page 6, for details.)

603-878-1441

IMPEDANCE MATCHING TRANSFORMERS AND LADDER LINE

Simple schemes for matching 50-ohm coax to ladder line

By Peter H. Anderson, KZ3K, 915 Holland Road, Bel Air, Maryland 21239

Hams enjoy experimenting with antennas. Simple wire types require a minimal investment, and the parts (consisting of nothing more than wire and insulators) are readily available. I've been working with 1:4 impedance transformers and ladder-line transmission line and would like to share what I've learned.

Introduction

A number of years ago I won my one and only door prize at a hamfest. It was an all-band "dipole-like" antenna consisting of 130 feet of wire center fed with 450-ohm transmission line. I couldn't wait to put up my new "toy" and give it a try. Imagine my disappointment when I found that it didn't work.

My preference for 450-ohm line used in conjunction with 1:4 ferrite transformers began with that antenna. I solved my impedance-matching problems using those transformers, and the antenna still works well today. I've since changed the feeds for all my other HF antennas to 450-ohm ladder line using the type of 1:4 impedance transformers shown in **Photo A**.

Ladder line has a lot to recommend it over coaxial cable. For instance, it's inexpensive and very light. Many of us depend on the smallest of twigs at the top of a tree to achieve maximum height when erecting a dipole. Anyone who has attempted to hoist the end of a dipole that's center fed with RG-8 can attest to the frustration of having those twigs break. The entire antenna falls, and you end up with a "V" shaped dipole.

Unlike coax, ladder line doesn't fill up with water, and I take a bit of comfort in being able to "see" whether the line is intact. Ladder line is also balanced and relatively lossless. Within hours of putting up a new antenna, I usually find myself wanting a bit more bandwidth than it can provide. Ladder line gives me flexibility in using a tuner that coaxial cable does not.

The difficulty with using ladder line seems to be in matching the 50-ohm rig to the 450-ohm tramsmission line and the transmission line to even the simplest of dipoles.* This drawback has become more apparent with the wide proliferation of solid-state rigs with a fixed 50-ohm output.

General analysis of 1:4 impedance transformer

Take a look at the general 1:4 impedance-matching autotransformer in **Figure 1**. It includes some practical implementations. Note that the output ("b" side) may be balanced or unbalanced depending on where ground is supplied on the input ("a" side).

A rigorous analysis of the network, which assumes only that the two coils are tightly coupled with one another, results in the following expression:**

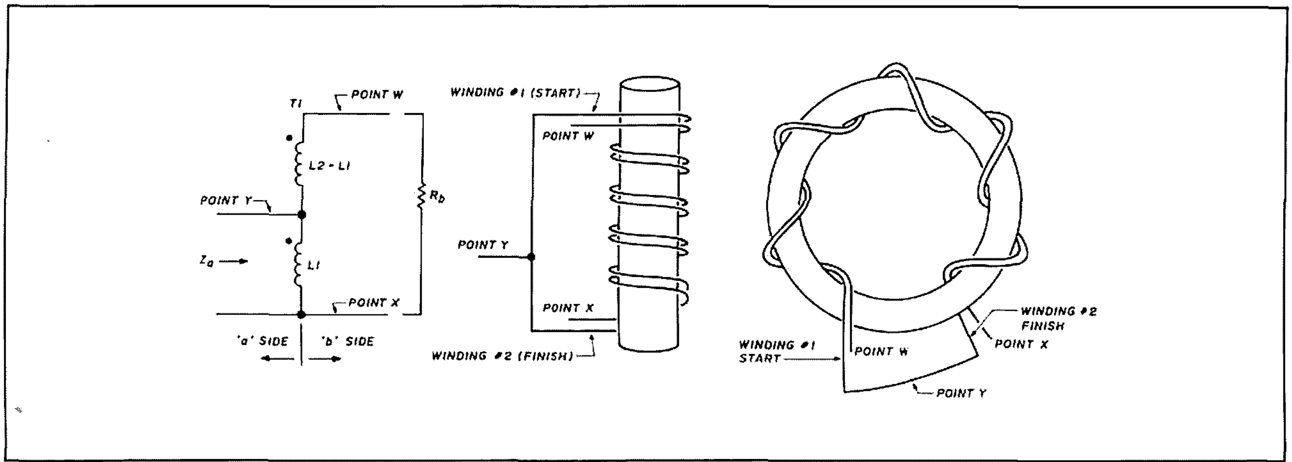
$$Za = \frac{Rb}{4.0 - j\,\dfrac{Rb}{Xl}} \qquad \textbf{(1)}$$

The j operator in the denominator indicates that the second term adds to the first at right angles, as shown in **Figure 2**. Note that if $2\pi fL1$ (the inductive reactance) is "large"

*Of course, the actual impedance ratio for transforming 50-ohm coax to ladder line is 1:9. I was unsuccessful in winding a 1:9 transformer that would provide satisfactory results. If you're interested in trying, you could use a pair of 1:3 transformers at either end to provide a closer 1:9 impedance transformation. Because of the low loss nature of 450-ohm ladder line, the additional loss due to impedance mismatch has negligible effects on the total power transformer.

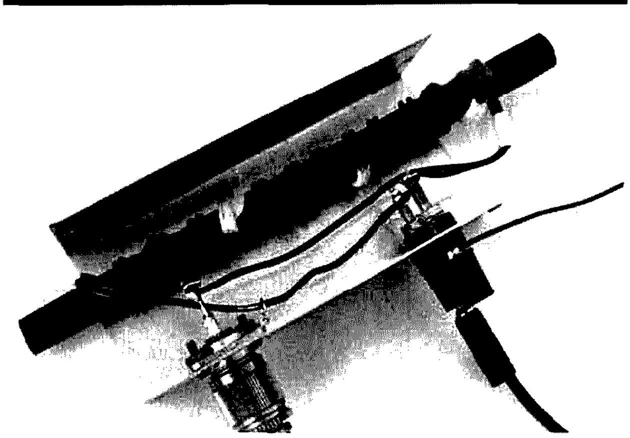
**Detailed derivations are available from the author for an SASE with one unit of postage. Computer analysis routines were written in Turbo Pacsal, Version 4.0 for IBM compatibles; a complete library of source code is available on 5-1/4" diskette for $5.00. You must have Turbo Pascal Version 4.0 (or later) and Turbo Graphix to support Version 4.0 to compile and execute these files. Hard copies of the source code listings are available for an SASE with three units of postage

FIGURE 1



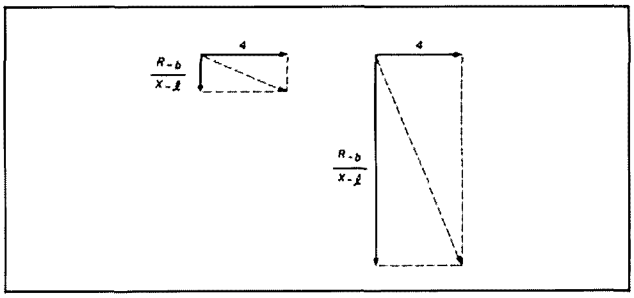
Schematic representation of 1:4 impedance transformer and implementations using a rod and toroid. The dots refer to the relative positioning of the windings. Each bifilar turn consists of two conductors tightly coupled to one another.

PHOTO A



An implementation of a 1:4 transformer using a ferrite rod. The design shown is unbalanced; ground is applied to one side of the transformer versis the center. Small applications of epoxy hold the rod in place.

FIGURE 2



The j operator indicates the quantities add at right angles. If Rb/Xl is small in relation to 4.0, the denominator is close to 4.0. However, if Rb is large in relation to 4.0, the denominator is Rb/Xl.

in relation to Rb, the first term in the denominator swamps the second and the expression reduces to:

$$Za = Rb/4 \tag{2}$$

The input impedance is Rb/4 and is purely resistive. The fact that the inductive reactance is large in relation to Rb is particularly important. It raises questions about how large "large" is, and about what happens if the inductive reactance isn't "large" enough.

Figures 3A and B provide a graphical analysis of Equation 1. Figure 3A shows that the ratio of the resistive portion of Za to Rb approaches 0.25 as the frequency increases for all values of Rb divided by L1 — that is, as the inductive reactance becomes "large" in relation to Rb. You'll note that at a particular frequency the ratio approaches 0.25 as Rb decreases in relation to L1, or as L1 increases in relation to Rb. Figure 3B is interesting because it shows that the reactive component seen on the "a" side may either increase or decrease with increasing frequency. Note that the reactive component is always positive (inductive).

Analysis of an inadequate design

The following example shows how to use Figures 3A and B to analyze the performance of an impedance transformer.

As one of my earliest projects, I attempted to match my 50-ohm transmitter to an end-fed wire which was about 135 ohms resistive at 3.5 MHz (see Figure 4). I reasoned that 135/4 wasn't 50, but it was close enough. I wasn't prepared for the 10 ohms plus the substantial reactive component which resulted, and I dropped the project in frustration.

I used the T-200-2 iron powder core (usually red in color).* It's probably the most common toroid-type core used at high HF power levels by the Amateur fraternity.

Consider a nine-bifilar turn arrangement at 3.5 MHz:

$$Ll \ (in\ \mu H) = (turns/100)^2 \times Al \tag{3}$$

where Al is in μH per 100 turns.

*The *ARRL Handbook* discusses toroid inductors in its "Electrical Fundamentals" chapter. It doesn't deal specifically with ferrite rods. The formulas for calculating inductance and turns are the same as the ferrite toroids (mix 61), except that Al is 49.

$$L1\ (in\ \mu H) = (9/100)^2 \times 120$$
$$= 0.972\ \mu H \quad \textbf{(4)}$$

Therefore, the inductive reactance at 3.5 MHz is:

$$Xl = 2\pi \times 3.5E\times10^6 \times 0.972E \times 10^{-6}$$
$$= 21.4\ ohms \quad \textbf{(5)}$$

This falls far short of the requirement that *Xl* be "large" in relation to Rb, which in this case was 135 ohms.

You can quickly calculate the resistive component of Za seen by the transmitter by referring to **Figure 3A**. Rb/L1 is nominally 138 ohms per μH. Using the curve for 150 ohms per μH as a guide, you can interpolate that the resistive part of Za/Rb at 3.5 MHz is nominally 0.075. This makes the resistive ratio of Za to Rb 1:13 — a far cry from 1:4. Additionally, the input resistance seen by the transmitter is close to 10 ohms.

Find the reactive component using **Figure 3B**. By picturing a curve between Rb/L1=100 and 200 you can estimate the reactive component ratio to be nominally 0.1. That is, 0.1×135 ohms=13 ohms. This means that at 3.5 MHz, the 135-ohm resistance is "reflected" to the transmitter as 10 ohms resistive plus 13 ohms reactive. Note that the reactive element is inductive. All in all, mine was not a successful venture.

Developing a workable design for an end-fed wire

Your next step is to design a functional transformer for this antenna. According to **Figure 3A**, you need an Rb/L1 ratio of less than 15 ohms per μH to get close to a 1:4 impedance ratio at 3.5 MHz. Because Rb is equal to 135 ohms, L1 must be larger than 135/15=9 μH. **Figure 3B** shows that the reactive component at 3.5 MHz is 0.04×135≈5.4 ohms, which is probably acceptable in relation to 33 ohms resistive. Use the relationship for iron powder toroids to find the number of turns required:

$$Turns = 100 \times \sqrt{(desired\ L1\ in\ \mu H/Al)}$$
$$= 100 \times \sqrt{(9/120)}$$
$$= 27.4\ turns \quad \textbf{(6)}$$

Note that each turn is bifilar consisting of two wires. Getting 55 single turns of no. 12 or 14 enameled wire on a T-200 core isn't possible. My own experience is that 15 bifilar turns is a practical maximum.

If you are confronted with the same problem at 7.0 MHz, look at **Figure 3A** and you'll see that an Rb/L1 of 25 ohms per μH is sufficient. Consequently, L1 must be a minimum of 135/25≈5.4 μH. I calculated the number of bifilar turns to be 21.

Now that I've gone through an analysis and design example, I'd like to offer some generalizations:

> On 3.5 MHz a ratio of Rb/L1 of 15 ohms per μH is adequate. At 7 and 14 MHz, ratios of 25 and 50 are adequate. Clearly, a broadband transformer designed using these criteria for one band will also perform on the higher ones.

So far I've considered an Rb of 135 ohms. We hams are usually interested in transforming Rb values on the order of several hundred ohms, and I concluded that the T-200-2 is very difficult to use on the lower HF bands. More than 21 bifilar turns simply don't seem to fit and I'm suspicious of parasitic capacitance; however, there's an easier alternative.

FIGURE 3A

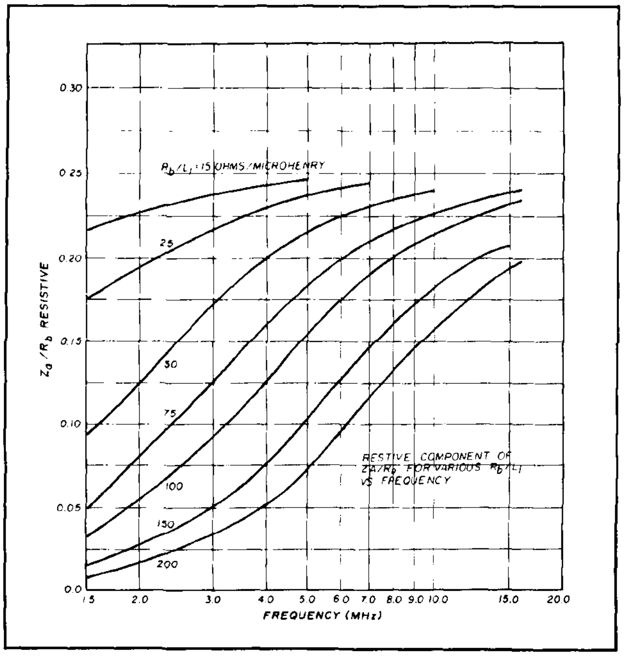
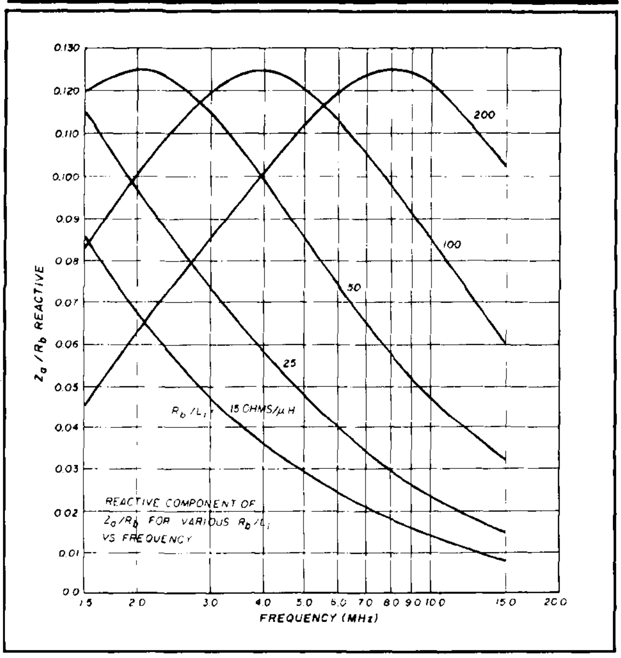


FIGURE 3B



Graphical analysis of *Equation 1*.

want to experiment with a toroid, the FT-240-61 might be a good prospect.

Consider a 13-bifilar turn arrangement at 3.5 MHz:

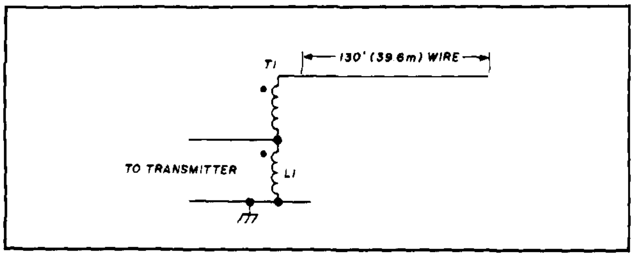
$$L1\ (in\ mH) = (turns/1000)^2 \times Al \quad \textbf{(7)}$$

Where *Al* is in mH per 1000 turns.

$$L1\ (in\ mH) = (13/1000)^2 \times 49 \quad \textbf{(8)}$$
$$= 8.28\ \mu H$$

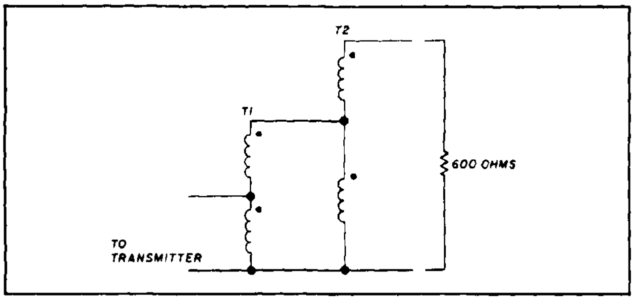
Assuming Rb is 135, the Rb/L1 ratio is 16.3 ohms per μH. Using the Rb/L1=15 ohms per μH curve in **Figure 3A** as

FIGURE 4



Using a noise bridge I determined the impedance of a 130-foot end-fed wire was nominally 135 ohms resistive. The transformer reflected this to present a 135/4 = 34 ohms load to the transmitter.

FIGURE 5



For large impedances two 1:4 transformers may be cascaded to realize a 1:16 impedance transformer. However, the inductive reactance of T2 must be large in relation to the load impedance. (See text.)

Ferrite toroids appear to be the answer. Unfortunately, they're relatively expensive and more susceptible to core saturation. I focused on the R61-050-750 ferrite rod; if you want to experiment with a toroid, the FT-240-61 might be a good prospect.

Consider a 13-bifilar turn arrangement at 3.5 MHz:

$$Ll \text{ (in mH)} = (\text{turns}/1000)^2 \times Al \tag{7}$$

Where Al is in mH per 1000 turns.

$$Ll \text{ (in mH)} = (13/1000)^2 \times 49$$
$$= 8.28\ \mu H \tag{8}$$

Assuming Rb is 135, the Rb/L1 ratio is 16.3 ohms per μH. Using the Rb/L1=15 ohms per μH curve in **Figure 3A** as a guide, you can calculate the resistive Za/Rb ratio at 3.5 MHz to be 0.23. This means the resistive portion of Za seen by the transmitter is 0.23×135=33 ohms, very close to 135/4. The reactive component, taken from **Figure 3B**, is less than 5 ohms.

As the frequency increases, the 2πfL1 becomes increasingly larger in relation to the Zb of 135 ohms, and the transformer operates correctly as a 1:4 transformer. The finished product is shown in **Photo A**.

Using cascaded 1:4 transformers for matching to larger impedances

You can modify this basic approach to match impedances exceeding 400 ohms to a nominal 50 ohms. See **Figure 5** for the circuit.

Consider a 600-ohm feedpoint impedance. A 1:16 impedance transformer consisting of two cascaded 1:4 transformers changes the impedance to 600/16=37.5 ohms, which is "close" to 50 ohms. Note that the Rb seen by the second tranformer is 600 ohms. To meet a requirement of Rb/L1 greater than 15, L1=600/15=40 μH (or 0.04 mH). The number of bifilar turns on a ferrite rod are calculated by:

$$\text{Turns} = 1000 \times \sqrt{(0.04/49)}$$
$$= 28.5 \text{ bifilar turns (57 conductors)} \tag{9}$$

This is tight, but not impractical. But the 58 bifilar turns (116 conductors) that would be required on a T-200-2 powder iron toroid, are simply not possible.

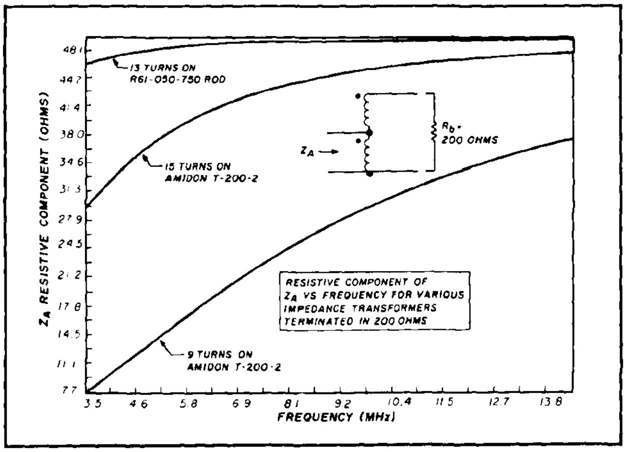
Note that the first transformer sees an Rb of 600/4=150. This tranformer can be implemented simply by using the 13 turns on a ferrite rod discussed above.

Observations

Plots of the resistance and the reactance seen on the "a" side for a number of different 1:4 transformers terminated in 200 ohms are shown in **Figures 6** and **7**. Using a noise bridge, I found that actual resistance measurements agreed closely with this theoretical performance.

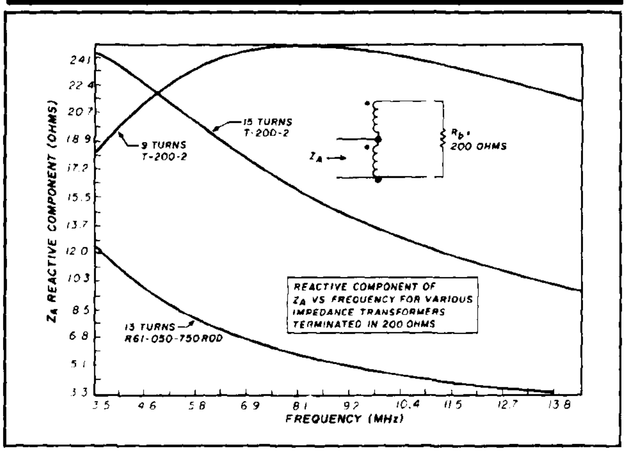
The results speak for themselves. If you want to match several hundred ohms on the 40 and 80-meter bands,

FIGURE 6



Resistive component response for various transformer materials.

FIGURE 7



Reactive component response for various transformer materials.

remember that the T-200-2 is not a Zb/4 transformer. The resistive portion of the impedance seen on the "a" side isn't anywhere close to one quarter and there's a substantial reactive component. On the other hand, the ferrite rod gives pretty good performance as a 1:4 arrangement across the HF spectrum from 80 meters up, and it might prove usable on 160 meters.

This doesn't rule out the T-200-2 as a matching transformer. You could null out the reactive component with a series capacitor, and use the "1:4 tranformer" to achieve the ratio you want by controlling the number of turns. For example, if you have a 300-ohm termination that you want to reflect as 50 ohms at 7.0 MHz, 50/300=0.167. Using **Figure 3A**, locate the point at X coordinate (7 MHz) and Y coordinate (0.167). I estimate that an Rb/L1 of nominally 130 ohms per μH passes through this point. Therefore L1=Rb/130=300/130=2.3 μH. Using a T-200-2 iron powder toroid:

$$\begin{aligned} Turns &= 100 \times \sqrt{(2.3/120)} \\ &= 13.8 \end{aligned} \qquad \textbf{(10)}$$

To determine the reactive component use **Figure 3B**. At 7.0 MHz and Rb/L1=130, the reactive Za/Rb is nominally 0.11. Therefore, Zb reactive=0.110x300=33 ohms. This inductive component might be nulled by using a series capacitor on the "a" side: $C=1/(2\pi \times 7 \times 10^6 \times 33)=688$ pF.

Such an arrangement will probably work well across the 40-meter band. However, it won't work on higher frequency bands. You're simply using the deficiency of the 1:4 arrangement to obtain a 1:6 match at a specific frequency.

Use of 1:4 transformers with ladder line

Using my new-found knowledge, I set up the circuit in **Figure 8**. I put two 1:4 transformers (like the ones mentioned above) back to back. A 100′ length of 450-ohm ladder line stretching out the back door, around the house, in the front door, and back to the shack provided me with access to both the "transmit" and "antenna" sides for power measurements.

Theoretically, the 50-ohm dummy load is reflected (transformed) as 200 ohms, and on the other side of the line the 200 ohms is reflected as 50 ohms. This results in a relatively high VSWR on the transmssion line, but relatively little power dissipation.

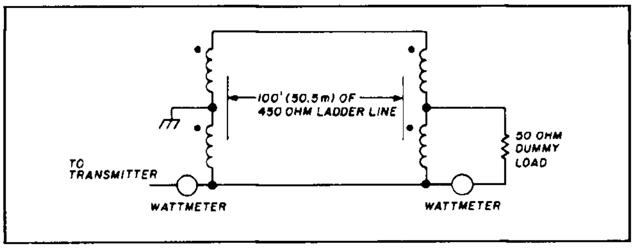
The results seemed too good to be true. The loss in the transmission line from the low end of 80 meters through the high end of 20 meters was less than 10 percent — including the two transformers. Viewed at the transmitter side of the arrangement, the SWR was better than nominally 2:1. On 160 meters the SWR was high, but correctable with a tuner. Even on 160 there was relatively little transmission line loss! Results on the 15 and 10-meter bands were difficult to interpret; this might be due to a less than ideal dummy load.

I have subsequently run tests on various lengths of ladder line and seem to be able to repeat my results. This leads me to conclude that most of the lost power is dissipated in the transformers. However, the efficiency of each transformer appears to be 95 percent.

Putting it all together

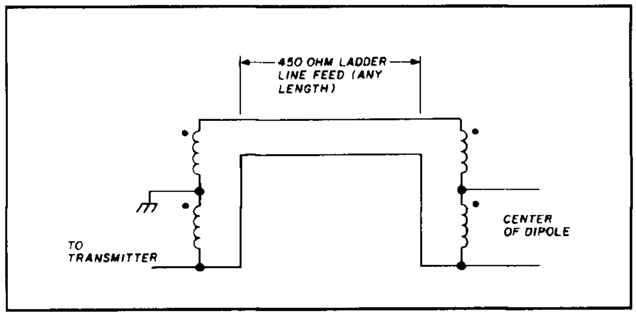
My next step was to apply this "discovery" to feeding dipole antennas normally fed with 50-ohm coaxial cable.

FIGURE 8



Two 1:4 transformers were connected back to back on the two sides of a 100-foot length of 450 ladder line. Ninety percent of the power delivered by the transmitter with a 50-ohm output impedance was delivered to the dummy load for 160 through 20 meters.

FIGURE 9



It appears feasible to feed 50-ohm loads using any length of ladder line terminated at each end with a 1:4 ferrite rod transformer over the HF bands from 80 meters and up. Note that the ladder line is balanced, transmitter ground is applied at the center of the transformer.

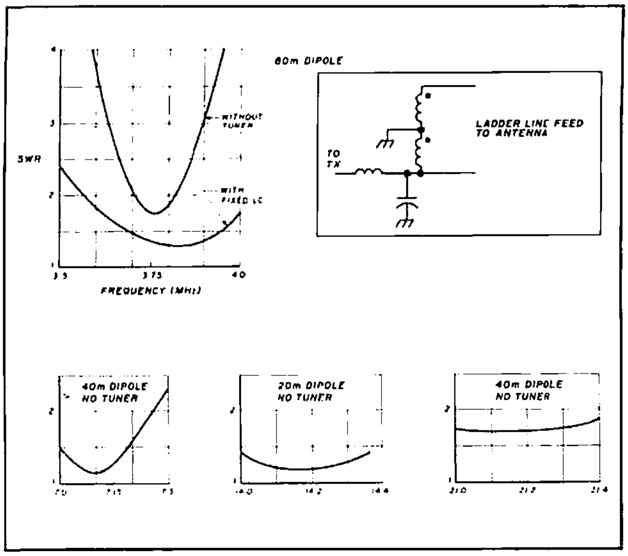
My previous attempts to feed dipoles with ladder line had drawbacks. One of my techniques involved terminating the ladder line directly at the center of the antenna, and on the transmitter side using a tuner capable of assuming different configurations. This let me load the antenna with "brute force."* The technique worked well, but I'm a firm believer in having a lot of antennas and I can't afford the space or money necessary to devote a tuner of this type to each antenna. My other technique was to use a delta match consisting of wires fanning down to meet the transmission line. I never had much luck with this method, and the family was forever getting entangled in wires that fell from the sky.

The arrangement in **Figure 9** has proven successful in feeding simple antennas without a tuning arrangement. The 1:4 transformer between the rig and the transmission line is an unbalanced-to-balanced arrangement, and ground is fed to the center of the transformer. The second transformer is mounted at the center of the dipole.

The results have been good. I've used this approach with standard dipoles on 80, 40, and 20 meters. The 40-meter dipole also performed well on 15 meters. **Figure 10** shows summarized results. In all cases except on 80 meters the SWR was better than 2:1 across the entire band. Using a very simple fixed series L/fixed shunt C tuner arrangement, I was able to obtain a match of close to 2:1 across the entire 80-meter band.

*Both matching techniques are discussed in detail in Doug DeMaw's book *W1FB's Antenna Notebook*, ARRL, 1987.

FIGURE 10



Three separate dipoles (80, 40, and 20 meters) were erected, each with separate feeds consisting of ladder line terminated with ferrite rod transformers. The 40-meter dipole was also used on 15 meters. Performance on 40, 20, and 15 was excellent with an SWR consistently less than 2:1 across the entire band. No tuner was required. On 80 meters, the bandwidth was relatively narrow and a very simple tuner consisting of a series L, shunt C was inserted on the transmitter side of the transformer.

One of the beauties of ladder line is that it's relatively lossless. Most of us don't have enough property to run 500 feet from the shack to that ideal antenna location — but some may, and this is the way to go.

Many hams want to ragchew on 3.9 MHz and also work CW or the DX window on the low end of the band using the same antenna. This poses a problem when feeding an 80-meter dipole with coax. You must choose a compromise resonant frequency and use a tuner for frequencies far removed from it. You can measure full power at the tuner, but the loss in the coaxial feed will be high. By using the ladder line in conjunction with the 1:4 tranformers at each end, you can use a tuner on the transmitter side of the transformer and have confidence that most of the power is reaching the antenna.

I've run all my dipoles at 700-watts output CW for several months with no evidence of flashover, saturation, or core heating. Even so, use some care. Attempting to load an 80-meter dipole on 40 meters presents the transformer with an impedance of several thousand ohms. This results in very high potentials, which may saturate the core and cause the windings to flash over.

Construction notes

The design which uses 13 turns on a ferrite rod has become my standard 1:4 transformer for impedances less than 400 ohms. The designs intended for indoor use may be either self-supporting or mounted on any miscellaneous mini box. The outdoor design is packaged in 3/4" PVC pipe. I used epoxy to secure the end caps and sealed the seams externally with RTV silicone. I fastened the entire assembly to a conventional ceramic insulator using cable ties.

Electrical parts are relatively easy to find. But I would stay away from miscellaneous toroids sold at hamfests. The computer industry manufactures many types of toroids to suppress the electromagnetic interference caused by high-speed switching noise, and these seem to have flooded the market. They are not suitable for this transformer application. There appears to be no standard color coding of ferrite toroids; unless you have a lot of faith in the seller, I wouldn't waste my time.

Three *Ham Radio* advertisters carry toroids and rods: Amidon, Palomar, and Radiokit. Amidon and Radiokit also carry the Scotch no. 27 glass tape I used to bind the two conductors tightly together. They also have a complete line of heavy Thermaleze™ insulated wire. I used 14 gauge.

Summary

I've provided a way to design and analyze 1:4 impedance transformers and given examples of some successful designs. I've had great success feeding dipoles with ladder line in the same way I'd feed them using coaxial cable. The materials are inexpensive and readily available. You don't need special tools, exotic metalwork, complex instrumentation, or large amounts of money. Give these designs a try, extend them to other types of antennas, and let me know your results. hr

A NOVEL METHOD FOR MEASURING CABLE ATTENUATION

By A. E. Popodi, OE2APM/AA3K, Moosstrasse 7, A-5020 Salzburg, Austria

The simplest way to determine cable loss is to measure the difference between input and output power with an RF wattmeter. A more accurate method is to measure the cable input and output voltages with an RF voltmeter and calculate the cable loss in nepers from the formula $\alpha = log_E \frac{Vin}{V\ell}$ where Vin is the input voltage and $V\ell$ the output (load) voltage. Both methods require a power source with an output impedance matching that of the cable and a known characteristic impedance Zo. Accuracy suffers if there is a matching error. Ground currents in the test setup can cause false readings. This method becomes very unreliable if α is small (i.e., the cable is short). If you want to measure the loss of a 2-meter length of RG-213 cable at a frequency of 28 MHz using this method, you'll find that the input and output voltage differ by only 0.89 percent. It's very difficult to make credible and meaningful measurements on short cables because of this small input/output voltage differential.

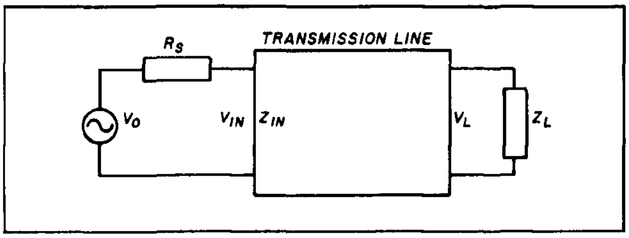
The method I've developed doesn't suffer from this shortcoming. It's based on the unique properties of an unterminated, quarter-wavelength transmission line driven from a low-impedance source. (See **Figure 1**.)

At the quarter-wavelength frequency, the cable input impedance (Zin) is very low — typically less than 1 ohm. The input voltage (Vin) is at minimum and the cable output voltage ($V\ell$) is high. Resistor Rs is the source impedance of the voltage source Vo.

The general expression for the ratio of input to output voltage is given in **Equation 1**:

$$\frac{Vin}{V\ell} = cosh\ (\alpha + j\beta) + \frac{Zo}{Z\ell} sinh\ (\alpha + j\beta) \qquad (1)$$

FIGURE 1



Block diagram of the setup for measuring cable attenuation.

where Zo is the characteristic impedance, $Z\ell$ is the load impedance, α is the cable attenuation in nepers, and β is the cable length in radians — in our case $\frac{\pi}{2}$. For the ideal case of the unterminated cable, this expression reduces to:

$$\frac{Vin}{V\ell} = cosh \left(\alpha + j\frac{\pi}{2}\right)$$

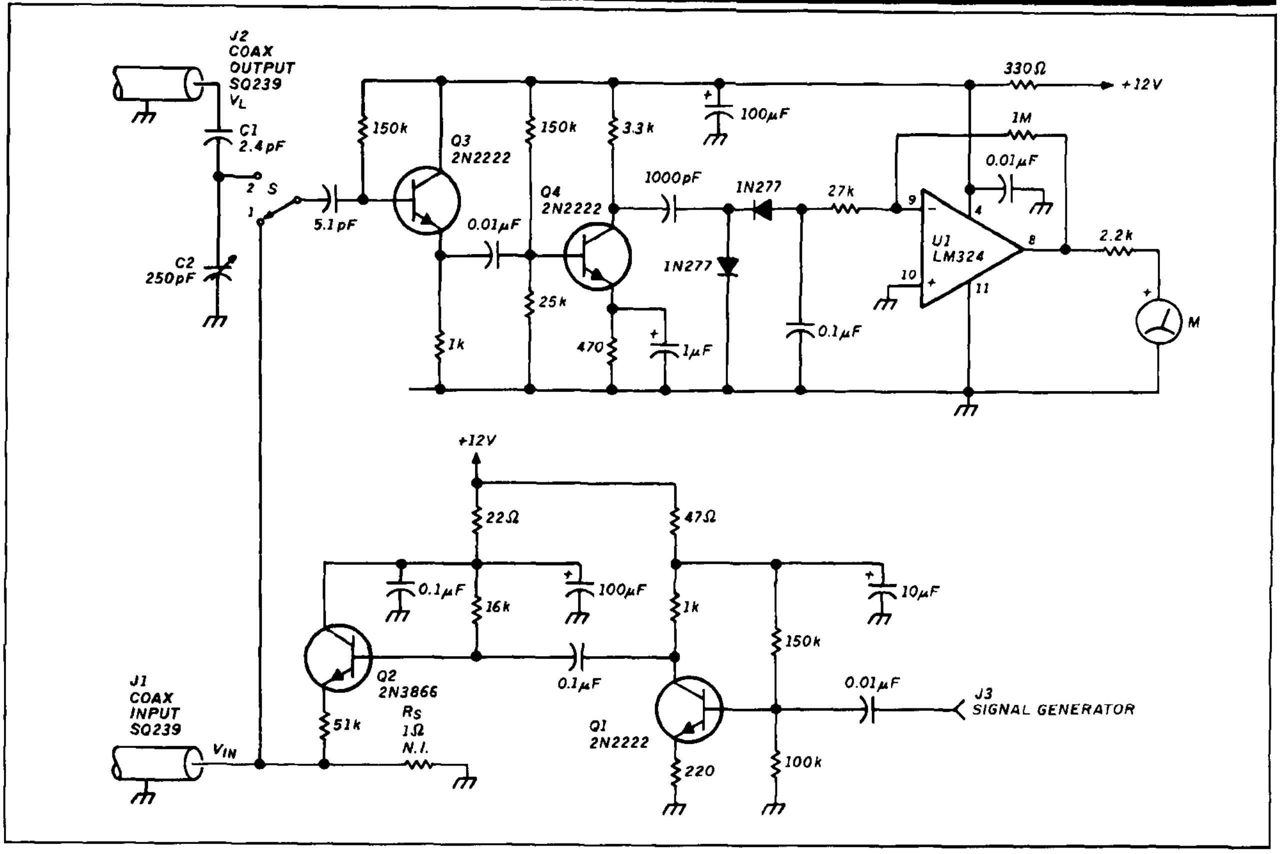
Using the formula $\cosh(\alpha + j\beta) = \cosh\alpha \cos\beta + j\sinh\alpha \sin\beta$ we have:

$$\frac{Vin}{V\ell} = j\ sinh\ \alpha \qquad (2)$$

Since α is a small number, sinh α is nearly equal to α. (For example, if α = 0.147 neper, the error caused by this simplification is only 0.5 percent.) The operator (j) indicates a 90-degree phase shift between the two signals. Using absolute values, you have:

$$\frac{Vin}{V\ell} = \alpha\ in\ nepers \qquad 1\ neper = 8.6859\ dB. \qquad (3)$$

FIGURE 2



Schematic of the complete test circuit for determining the voltage ratio for accurately determining the cable attenuation.

The cable attenuation in nepers is very nearly equal to the ratio of the two voltages. As a result, $V\ell$ may be 50 times larger than Vin, depending on cable loss.

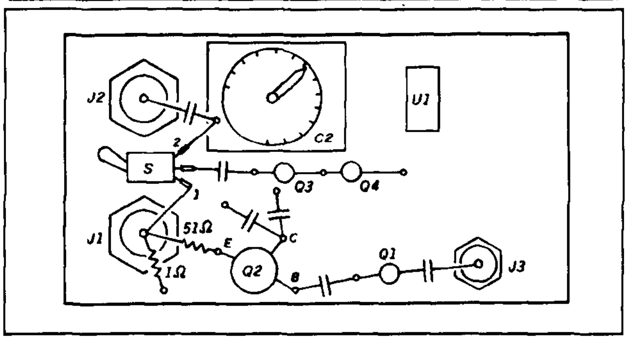
Equation 2 is only valid if load impedance $Z\ell$ is infinitely high. In practice, you have a capacitive load impedance ($Z\ell$) and a slightly inductive source impedance (Rs). That means you must use **Equations 1** and **6** to evaluate the effect on the voltage ratio $\frac{Vin}{V\ell}$.

You don't need a precision RF voltmeter to measure this voltage ratio if you use a capacitive voltage divider for $V\ell$ and compare the divided voltage with Vin in a simple voltage comparator. This gives you the advantage of being able to make Zin very high. **Figure 2** shows the schematic of the complete test circuit.

A signal generator is connected to the input of isolation amplifier Q1 that feeds the emitter follower and cable driver Q2. Resistor Rs is a noninductive 1-ohm resistor that presents a low source impedance to the cable input at terminal J1. At the cable output (J2), there is a capacitive voltage divider consisting of a small 2.4-pF fixed capacitor (C1) and a 250-pF variable capacitor (C2). Switch S alternately connects Vin (position 1) or the divided voltage $V\ell$ (position 2) to a post-amplifier (consisting of emitter follower Q3 and amplifier Q4) with high input impedance. The rectified RF signal is amplified in operational amplifier U1 that drives indicator instrument M.

You must *carefully* choose the biasing of transistor Q1 and emitter follower Q2 to avoid waveform distortion in Q2. Because the cable output waveform is always better than a possibly distorted input signal, voltage comparison may be degraded due to waveform differences between the two signals. **Figure 3** shows a recommended layout for the test fixture.

FIGURE 3



Component layout of the cable-attenuation test circuit.

Switch S is mounted between connectors J1 and J2. (I recommend using a silver-plated brass plate as the mounting surface in order to reduce the effect of ground loops.) It's important that the lead lengths to and from capacitor C1 be as short as possible to obtain a frequency-independent capacitive voltage divider.

Test procedure

Connect the cable to J1 and J2. Put switch S in position 1 and adjust the signal generator near the estimated quarter-wave frequency for an input voltage minimum, with a meter deflection of perhaps 80 percent. With the switch in position 2, adjust variable capacitor C2 for equal meter deflection. Capacitor C2 must be measured in the circuit with a capacitance bridge, with capacitor C1 disconnected, and with switch S in position 2. You can calibrate the dial of C2 directly in nepers or picofarads. Calculate the divider ratio from **Figure 4**. If, for instance, C2 = 153 pF and C1 = 2.4 pF, the voltage ratio is:

$$\frac{V\ell}{Vin} = \frac{153}{2.4} + 1 = 64.75$$

and the cable loss is:

$$\alpha = \frac{1}{64.75} = 0.0154 \text{ neper or } 0.133 \text{ dB.}$$

How to find cable loss at other frequencies

Unfortunately, my method supplies cable loss for only one frequency. But if you make a second measurement at three times the frequency (pertaining to a three-quarter wavelength cable), you now have two sets of attenuations $\alpha 1$ and $\alpha 2$ and two frequencies F1 and F2. Using the interpolation method described by K2BT,[1] you can calculate the loss at any other frequency with the following procedure:

First calculate two constants, m and n:

$$m = \frac{\alpha 1 F2 - \alpha 2 F1}{F2\sqrt{F1} - F1\sqrt{F2}} \qquad n = \frac{\alpha 2\sqrt{F1} - \alpha 1\sqrt{F2}}{F2\sqrt{F1} - F1\sqrt{F2}}$$

The cable loss $\alpha 3$ at the frequency F3 is then:

$$\alpha 3 = m\sqrt{F3} + nF3 \qquad \textbf{(4)}$$

Here's a practical example:

Coaxial cable RG-213, 1 = 9.58 meters. The full-wave frequency of the 9.58-meter cable is:

$$\frac{300}{9.58} \cdot 0.66 = 20.668 \text{ MHz}$$

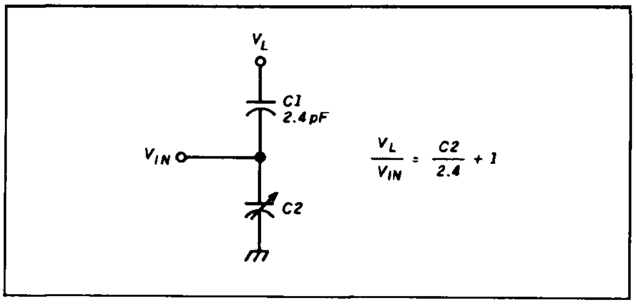
assuming a velocity constant of 0.66. This means that for a frequency of 5.167 MHz the cable is a quarter wavelength long. This brief calculation only helps you find the approximate value of the measurement frequency. Its exact value depends on the minimum value of Vin. The next minimum occurs at the three-quarter wavelength frequency of 15.417 MHz. In general, the first measurement frequency is the lowest frequency on the frequency dial where Vin has its first minimum.

Assuming that the minimum of Vin occurs at 5.116 MHz, the capacitor settings are: C2 = 153 pF and C1 = 2.4 pF.

$$\frac{V\ell}{Vin} = \frac{153}{2.4} + 1 = 64.75 \qquad \alpha 1 = \frac{1}{64.75} = 0.0154 \text{ N}$$

The measurement at frequency F2 = 15.348 MHz is: C2 = 79 pF and C1 = 2.4 pF.

FIGURE 4



Capacitive voltage divider circuit used in the test circuit at the output end of the coax under test.

$$\frac{V\ell}{Vin} = 33.91 \qquad \alpha 2 = 0.0295 \text{ N}$$

Calculating factors m and n from $\alpha 1$ = 0.0145 N, F1 = 5.116 MHz, and $\alpha 2$ = 0.0295 N, F2 = 15.348 MHz gives m = 0.00582 and n = 0.000436.

If you want the loss at frequency F3 = 28 MHz:

$$\alpha 3 = m\sqrt{F3} + nF3 = 0.043 \text{ N.}$$

Measurement accuracy

Now you need to find out how large an error results if you assume the simple relationship $\frac{Vin}{V\ell} = \alpha$ which the test set is delivering.

In reality, the source impedance Rs, even when purely resistive, affects the tuning frequency for minimum input voltage Vin. The load impedance $Z\ell$ is not infinitely large, and also affects the tuning. In our example, capacitor C1 = 2.4 pF has a capacitive reactance of $Z\ell = -j2962$ ohms at 5116 MHz using **Equation** 1 you get:

$$\frac{Vin}{V\ell} = \cosh(\alpha + j\beta) + j\,0.003857 \sinh(\alpha + j\beta) \qquad \textbf{(5)}$$

According to the test procedure, you must adjust the frequency for minimum input voltage. You can calculate Vin from **Figure** 1 to:

$$Vin = Vo\,\frac{Zin}{Zin + Rs}$$

Since

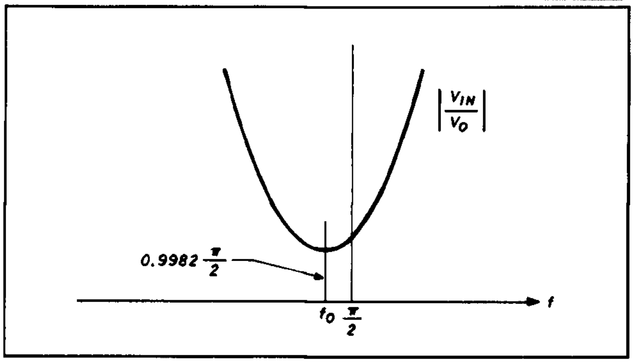
$$Zin = Zo\,\frac{Z\ell + Zo\tanh(\alpha + j\beta)}{Zo + Z\ell\tanh(\alpha + j\beta)}$$

we can calculate $\frac{Vin}{Vo}$ to:

$$\frac{Vin}{Vo} = \frac{Zin}{Zin + Rs} = \qquad \textbf{(6)}$$

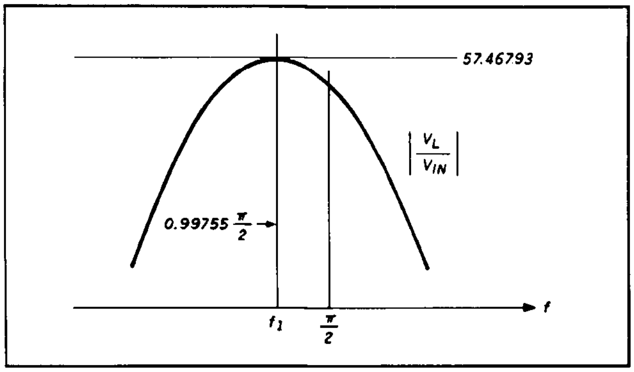
$$Zo\,\frac{1 + \frac{Zo}{Z\ell}\tanh(\alpha + j\beta)}{Zo\ 1 + \frac{Zo}{Z\ell}\tanh(\alpha + j\beta) + Rs\,\frac{Zo}{Z\ell} + \tanh(\alpha + j\beta)}$$

FIGURE 5



Typical plot for the results of *Equation 6*.

FIGURE 6



Plot of $V\ell/Vin$ versus frequency for Z1 = −j12962 ohms and α=0.0174 nepers.

A typical plot of **Equation 6** is shown in **Figure 5** which is drawn for Rs = 1 + j0.2 ohms, $Z\ell$ = −j12962 ohms, and α = 0.0174 N. It can be shown that the input voltage minimum occurs to the left of the $\frac{\pi}{2}$ point (frequency Fo) if there's a capacitive load $Z\ell$ and resistive Rs. If you have a slightly inductive source impedance Rs and an infinitely high $Z\ell$, the voltage minimum will occur to the right side of the $\frac{\pi}{2}$ point. Which effect dominates determines the location of the minimum. However, the deviations are very small. Plots **5** and **6** are frequency independent; the point π denotes the quarter-wavelength frequency. All voltage ratios are in absolute values.

Having found the frequency Fo from **Figure 5** by using **Equation 6**, you must insert its value into **Equation 5** to find $\frac{V\ell}{Vin}$. **Figure 6** is the plot of $\frac{V\ell}{Vin}$ versus frequency for $Z\ell$ = −j12962 ohms and α = 0.0174 N (resistor Rs doesn't affect this ratio).

The maximum value of $\frac{V\ell}{Vin}$ occurs at the frequency F1 of 0.99755 $\frac{\pi}{2}$, giving a $\frac{V\ell}{Vin}$ value of 57.46793, whereas the true voltage ratio for the cable attenuation of α = 0.0174 N is:

$$\frac{V\ell}{Vin} = \frac{1}{0.0174} = 57.47126$$

This represents an error of only 0.0058 percent for the ideal case when the minimum of Vin occurs at the same frequency as the maximum of $\frac{V\ell}{Vin}$. This isn't always the case, but the deviation is small. You must measure $V\ell$ at the frequency where Vin has its minimum, not at the frequency where $V\ell$ has its own maximum, because the maximum of $V\ell$ doesn't coincide with the maximum of $\frac{V\ell}{Vin}$.

In reality, the frequency Fo may deviate slightly from this ideal F1 value, depending on the canceling effect of Rs and $Z\ell$. This error-reducing effect is a welcome and unexpected benefit, since Rs is always slightly inductive because of the difficulty in realizing a noninductive 1-ohm resistor.

In the example, the frequency Fo for the lowest input voltage is 0.9982 $\frac{\pi}{2}$. The corresponding $\frac{V\ell}{Vin}$ ratio, as calculated from **Equation 5**, is 57.3697. This amounts to an error of only 0.18 percent. The error would be 0.4 percent without the capacitive load. In other words, the "minimum Vin" method is quite accurate, and its accuracy depends mainly on the capacitive voltage divider. It shows that the measurement error in the practical case of capacitive load and inductive source impedance is even smaller than that of the ideal case with infinitely high load impedance.

If you make a direct RF voltage measurement of Vin and $V\ell$ without the test set, you must connect a capacitor whose value is equal to the meter capacitance at the cable output while you adjust the frequency for minimum input voltage. Remove this capacitor when you measure $V\ell$ with the meter, but don't alter the frequency setting. Even if you don't make this substitution, the loss measurement is still accurate enough for most applications.

Summary

Accurate and credible measurement of cable loss (calculated as the difference between input and output power) is difficult if the loss is small (for a short cable or at low frequencies).

The ratio of output to input voltage of a transmission line that is unterminated and driven from a low source impedance has a maximum value when measured at odd multiples of the quarter-wave frequency. The reciprocal of this ratio is very nearly equal to the cable loss in nepers within an error of less than 1 percent.

There are two ways of finding this maximum. The first involves the direct measurement of Vin and $V\ell$ with a calibrated RF voltmeter. The second is based on the voltage comparison between the capacitively divided output voltage and the input signal; it doesn't require a calibrated RF voltmeter. The capacitor dial can be calibrated in picofarads or directly in nepers.

By repeating the measurement at the three-quarter wavelength frequency, you'll get two sets of attenuation and frequency values. You can find the cable loss at any frequency between the measuring points by using a simple interpolation method. However, actual tests show that the equations also render excellent results for frequencies much higher than the measuring frequency. The two error sources of this method, the inductive source impedance and the capacitive load, tend to cancel each other and the measurement accuracy is mainly dependent on the accuracy of the capacitive voltage divider.

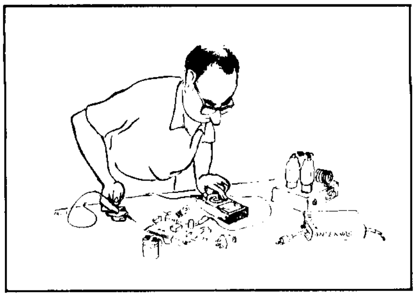
One great advantage of this method is that you don't have to know the characteristic impedance of the cable or its velocity factor; therefore, no mismatching error exists. The method is especially useful when the cable loss is small, making conventional loss measurement unreliable. Even a piece of coax as short as 1 meter can be measured accurately.

Practical cable tests, together with the interpolation method, produced excellent agreement with published data sheets. hr

REFERENCE

1. Forrest Gehrke, K2BT, "Real Coax, Impedance and Phase Relationships," *Ham Radio*, April 1987, pages 8-14.

Ham Radio Techniques



Bill Orr, W6SAI

ANTENNA TIME

Spring is just ahead and it's time to start thinking about worthy antenna projects. I've received a number of letters about unusual antennas that I think are interesting. Here are some of them for your consideration.

The 10-meter "Hentenna" loop

Harold Muensterman, N9DEO, sent me data on this clever little antenna developed by JE1DEU of Sagamihara City, Japan. Local hams were amused by the loop; hence the name — "hen" means curious in Japanese. "Hen-antenna" was quickly shortened to "Hentenna." It's shown in **Figure 1**. This antenna's virtue is that it has very little "wingspread" and is quite unobtrusive.

The array has two one-sixth wave radiators separated vertically by a half wavelength. To feed them, connect the tips and tap the vertical wires with a coax feedline. Polarization is horizontal.

Hentenna construction is simple. You use a single mast; try a TV-style push-up one. Make your horizontal sections out of 5/8-inch diameter aluminum tubing bolted to a mounting plate, and attach the plate to the mast with U-bolts. Use enamel-coated copper wire for the antenna's vertical sections.

Feed the Hentenna with a balun and coax line. Run your feed wires from the balun to the vertical wires. Adjust for lowest SWR by moving the feed wires up or down the vertical wires. Copper alligator clips are ideal for this; you can remove them and make joint solders when you find the correct points. The points should be about 36 inches above the bottom tube for 10 meters.

The Hentenna provides a figure-eight pattern at right angles to the antenna plane. Gain is estimated at about 2.5 dB over a dipole. Bandwidth is very broad. By changing the length of the vertical wires, you can move the design frequency to any point in the 10-meter band.

A hanging unipole antenna for 160 meters

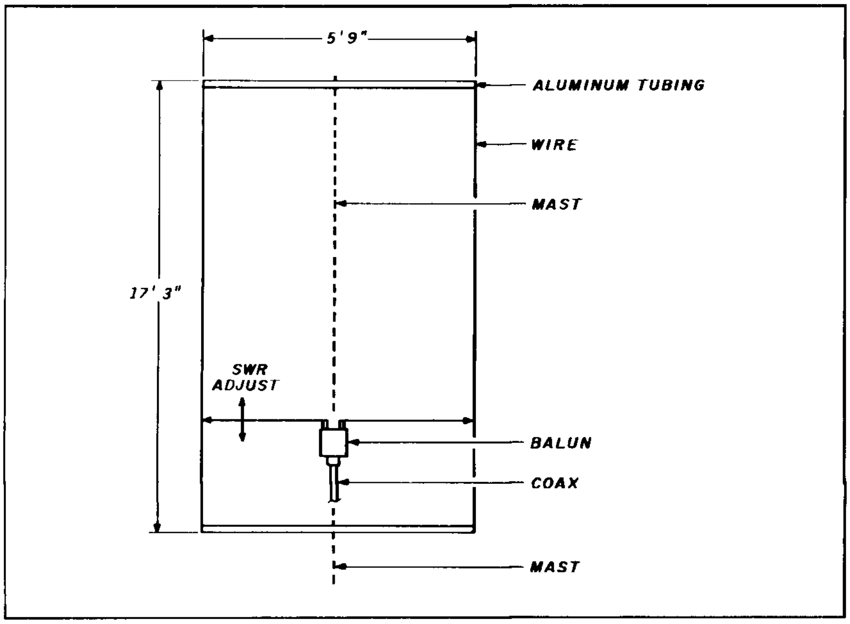
Phil Morgan, WDØP, uses a simple folded monopole for 160 operation (**Figure 2**). Phil says, "Being a cheapskate, I put up this antenna made out of Radio Shack loudspeaker cable. I used a tree limb about 46 feet above the ground. I zipped 45 feet of this wire down the middle, soldered the leads together at one end and spaced it down its length with a half-dozen spreaders made of 6-inch pieces of 1/2-inch PVC tubing. I grounded one wire at the bottom and fed the other. Since the antenna was too short for 160 operation, I soldered a single wire to the top of the vertical portion and trimmed its length to resonate the whole works in the middle of the 160-meter band. I use my Heath SA-2060 Transmatch to give me access to the whole band.

"I have a pretty good ground system — an old, abandoned underground water tank, plus four 50-foot radials made of 2-foot wide chicken wire fencing laid on the ground. I'm not a big DXer, but have worked Hawaii and Cape Verde Islands on 160 using this lash-up. If you change the length of the single wire, the antenna will also work on 80 meters."

Any information on GFI?

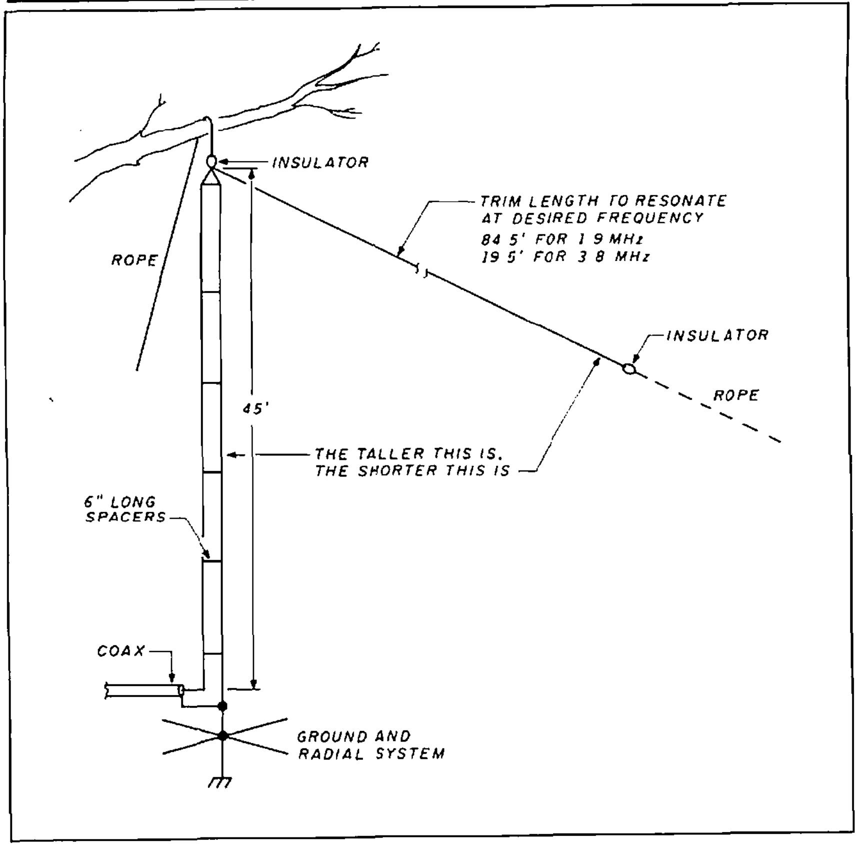
In closing, Phil asks if anyone has

FIGURE 1



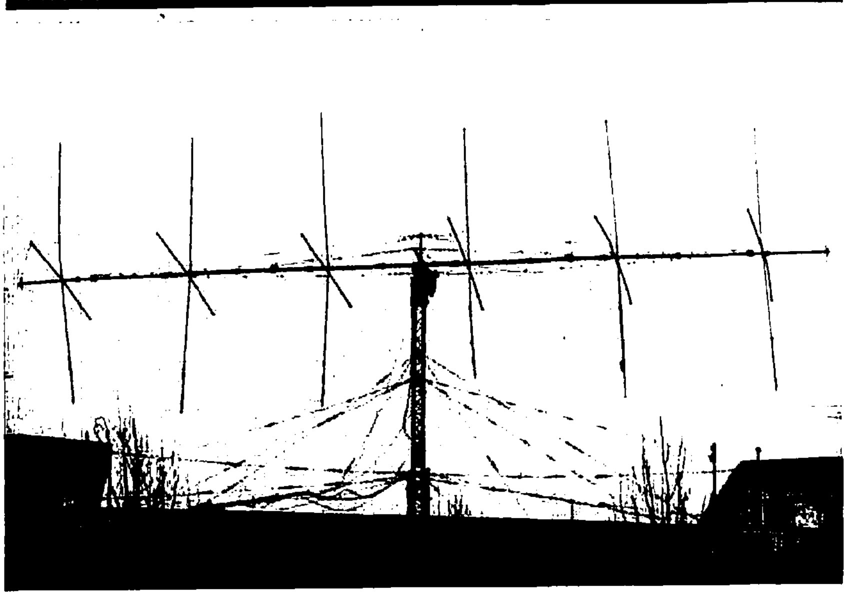
"Hentenna" for 10 meters. Adjust tap points for lowest SWR.

FIGURE 2



The 160/80 meter antenna at WDØP.

PHOTO A



The 6-element, 14-MHz Quad at UA6LA is built on an 80-foot, trussed boom.

information on Ground-Fault-Interrupter interference (GFI). He's run into these pesky devils in trailer parks and finds they're very sensitive to RF. He notes that the slightest tap of the key or word spoken into the mic will cause these GFIs to trip. Phil has also found GFIs on boat docks, so hams operating around a marina may have the same problem. Any answers to this? Write me if you have a solution.

A six-element quad on an 80-foot boom!

I received a note and photo from Victor Trachenco, UA6LA, Rostov-on-Don, USSR. He's the proud owner of a six-element, 20-meter quad (Photo A). This monster is built on a well-trussed 80-foot boom. So when you hear the blockbuster signal from UA6LA, you'll know it comes from this giant antenna!

The K6WZ tilt-over tower

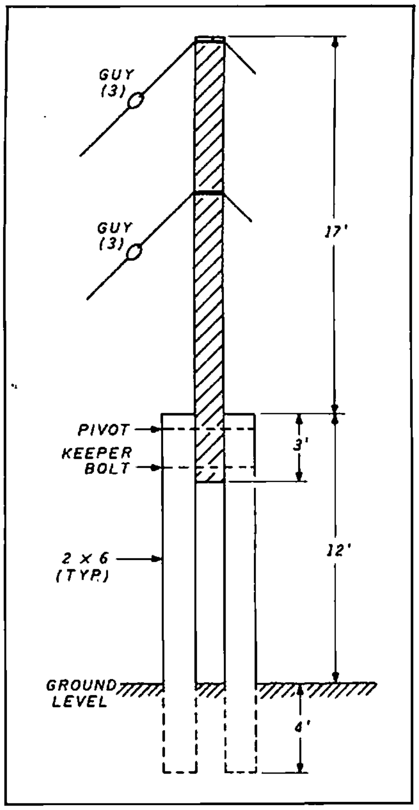
I mentioned in a previous column that I'd seen a lot of tilt-over towers in New Zealand, but not many in the United States. Some of you have been kind enough to send me information on homemade tilt-over towers. Here are two interesting designs.

Carl Steavenson, K6WZ, of Herington, Kansas, built the wood tower shown in Photo B and Figure 3. It's about 30 feet high. The fixed, bottom portion is made of two 2 × 6 pieces of pressure-treated lumber 16 feet long. They are treated, before assembly, with Thomson's Waterseal. The 2 × 6's are sunk about 4 feet in the ground.

The top tilt-over portion of the tower is made of a single section of 2 × 6 material 20 feet long. It's pivoted near the top of the two lower sections with a heavy bolt. The pivot point on the top section is placed so that about 17 feet extend above the lower supports, and there's a 3-foot lever arm below the pivot point. The pivot is made of a short piece of half-inch pipe with a heavy bolt running through it.

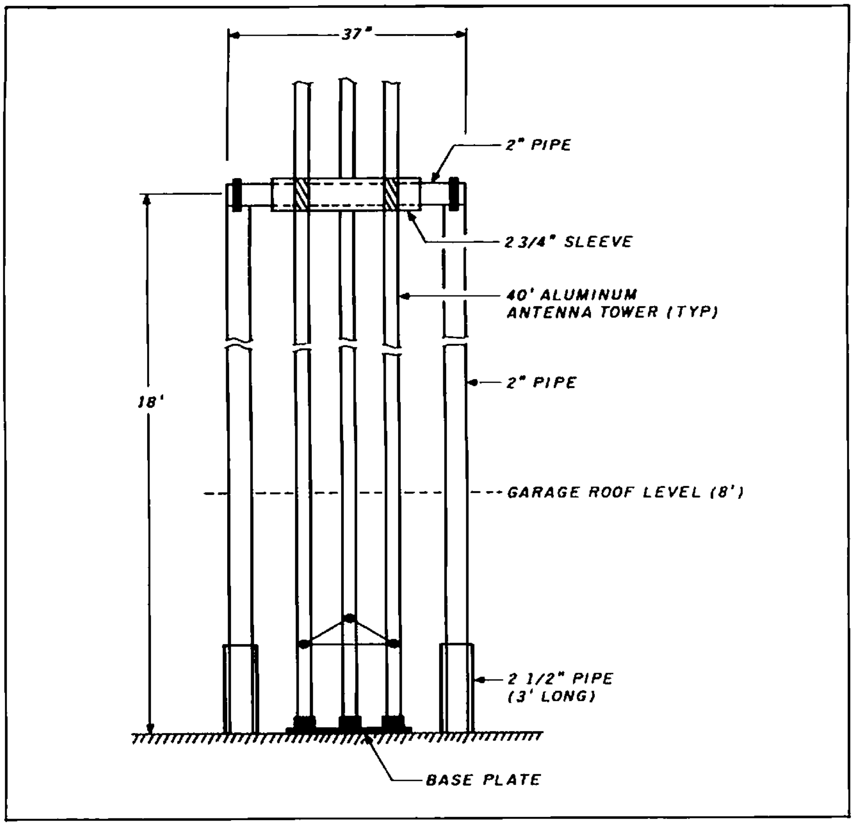
A rotating mast of 10-foot TV mast sections runs up the wood mast. The rotor is about 8 feet above ground and turns the mast sections which support the antenna. The mast sections are attached to the wood tower by large eye bolts whose "eyes" are opened just enough to pass the rotating metal mast. The rotor sits on a small metal shelf bolted to the tilt-over section. To counterweight the tower, a few pieces

FIGURE 3



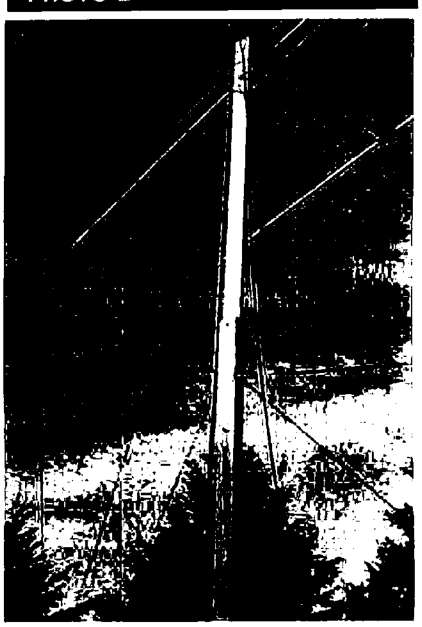
Layout of K6WZ tilt-over tower.

FIGURE 4



Tilt-over tower support at K9BX.

PHOTO B



The tilt-over tower at K6WZ. Made of 2 × 6 lumber. The tower is about 30 feet high. Rotor is placed near ground level and antenna is turned by supporting pipe.

of scrap metal are bolted to the shelf below the rotor.

To tilt the tower, Carl loosens two top back guys and removes the keeper bolt. He uses a little care and safety ropes, and over it comes!

Carl built the original tower in California 15 years ago. It was so successful that he built a duplicate when he moved to Kansas. He's worked 214 countries on RTTY with this low-cost, simple tilt-over antenna system, using a small triband beam!

The K9BX tilt-over tower

"Doc" Roberts, K9BX, of Rothschild, Wisconsin, has adapted a commercial tower to a tilt-over design (Figure 4). He's had this arrangement for 20 years and is very pleased with it.

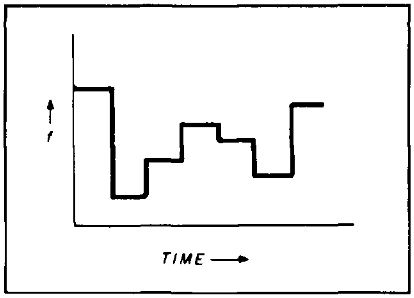
The tilt-tower support frame is 18 feet tall and made of salvaged pipe. Each arm is built from 2-1/2 inch schedule 40 pipe on the bottom section, and 2-inch pipe on the top section. Running across the top of the tower is a 37-inch crossarm of 2-inch pipe welded into ears at the tops of the vertical legs. A 2-3/4 inch pipe, about 24 inches long, fits over the crossarm of the tower and functions as a pivot point. It is fastened to the tower.

The base of the tower (a 40-foot aluminum model) is bolted into a base mount anchored in concrete. The tower sits alongside a flat-roofed garage; two of the vertical legs are anchored to the garage about 8 feet above ground.

To lower the tower, a pulley and rope system is attached to the bottom, the bolts anchoring the tower to the base plate are removed, and the tower is lowered manually. When the tower reaches a horizontal position, the rope is secured. The tower is then about 7 feet above the roof level, and the antenna is in an ideal position to work on. (Doc has a two-element quad on the tower.)

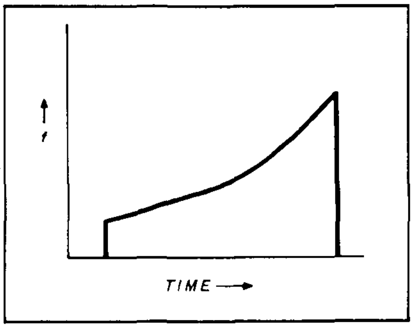
Doc says that after 20 years of wind action on the tower, the bolt holes near the tilt-over joint have become slightly elongated. He's reinforced these points and has added a set of top guy wires. Up to this time, it had been a freestanding tower, anchored only at the top of the garage.

FIGURE 5



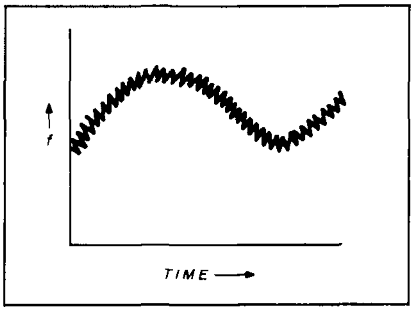
Frequency-agile ("hopping") signal.

FIGURE 6



Radar "chirp" signal.

FIGURE 7



"Jitter" signal.

Things that go "bump" in the night!

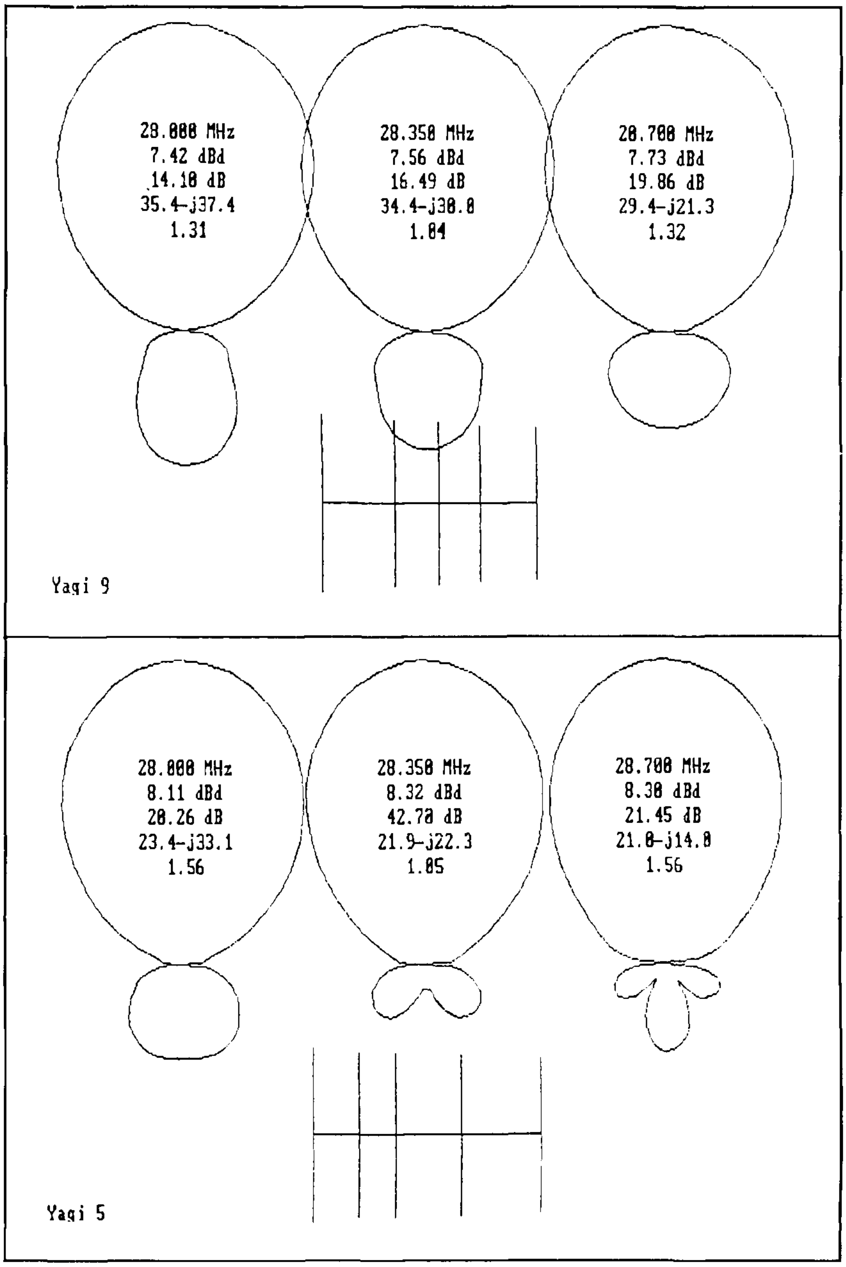
Back in the "good old days," emission was either phone or CW. As time went on, things became more complicated. A0 Emission was unmodulated carrier, A1 was CW, A2 was tone-modulated CW, A3 was phone, A4 was facsimile, and A5 was television. There were also "F-type" emissions covering FSK, FM, and so on. Things were getting confusing!

Today there's a half-page of "emission classifications" in the *ARRL Handbook*! Single sideband, suppressed carrier (SSB) is listed as J3E (formerly A3J). That's simple enough. But if you're running "angle modulation" (FM) with 5-kHz deviation and a maximum modulation frequency of 3 kHz, your emission classification is 16K0F3EJN. If you use phase modulation, your classification is 16K0G3EJN. And poor old Morse code is now 150HA1AAN (if you're sending 60 wpm).

What this means is that hams now hear a lot of funny signals in and out of the ham bands. They may or may not have emission classifications but, for the most part, they certainly aren't ham signals. Here are some of the more interesting ones.

Figure 5 is a sketch of a frequency-agile ("hopping") signal which varies frequency in a predetermined manner, with the receiver locked to the rapidly

FIGURE 8



Top: Commercial 10-meter beam. Bottom: Commercial beam optimized. Constants listed are frequency, gain, F/B ration, input impedance, and SWR.

shifting signal. The hopping sequence often lands the signal in a ham band; you hear a quick burst of voice or other modulation, and the signal is gone. Does anyone know who the "hopper" is? I don't.

Figure 6 shows a representation of a "chirp" emission. This is often used with a radar, where the frequency varies with time. Figure 7 illustrates a "jitter" signal. The jitter varies with frequency, within a predetermined time frame.

There are other weird signals including: the well-known Soviet "Woodpecker", OTHR (Over-the-Horizon Radar), and Soviet missile tracking radars that occasionally pop up in the 10 and 12-meter bands. American OTHR is also on the air, but hops about randomly, and so far has caused no lasting interference in the hams bands. Other OTHRs on the air in various countries sometimes appear in an Amateur band.

Countless other curious things (like single-letter beacons) abound, and they often cause QRM in and out of the ham bands. There are also mysterious "numbers" stations, which repeat coded number groups throughout the HF range.

All of these signals cause QRM in an already jammed radio spectrum. Unfortunately, it's often easy to turn them on but not so easy to turn them off! Happy listening!

The Yagi optimizer disk

Brian Beezley, K6STI, has come up with another interesting disk for IBM-PC and compatible users. It's called the "Yagi Optimizer, YO version 1.00." This program automatically optimizes a Yagi antenna for maximum forward gain, best pattern, and minimum SWR. The package includes models for matching networks, element tapering, element-to-boom mounting plates, frequency scaling, and element taper scaling.

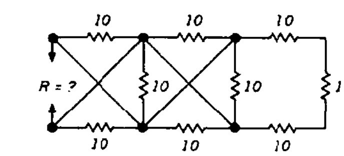
The YO program also plots antenna radiation patterns at the central design frequency and at the band edges. Best of all, YO has been designed to work alone or in conjunction with MININEC3, the high-accuracy general purpose antenna analysis program. This makes it convenient to analyze and optimize a Yagi previously analyzed with MININEC3.

Figure 8 shows an example of "before" and "after" optimization of a commercial 5-element 10-meter Yagi. Interested? Write to Brian (507-1/2 Taylor Street, Vista, California 92084) for full details.

The Dead Band Contest

I appreciate all the letters and cards I've received in response to this little exercise. Thank you all very much! This month's quiz is an easy one. I'll give the answer next month. Find the input resistance to the network in Figure 9. Each resistor is 10 ohms.

FIGURE 9



What is input resistance?

THE MICROFARAD COUNTER

By Hans Evers, PA0CX, Wintererstrasse 3, D-7800 Freiburg, W. Germany

You can often find second-hand electrolytic capacitors at amazingly low prices at flea markets and surplus stores. The reason? Nobody trusts them (the capacitors, that is).

It isn't always easy to check the quality of a polarized capacitor. The number of microfarads may exceed the range of your measuring bridge, and it's rather unusual to find provisions for applying the necessary DC polarization during the measurement. Also, a quick assessment of possible leakage in a large capacitor could lead to problems.

With these considerations in mind, I decided to build a basic test box. My efforts resulted in an almost suspiciously simple schematic diagram. Yet the test box (though small enough to fit in your pocket) measures not only how many microfarads there are with reasonable accuracy, but whether the capacitor under test leaks. Although the circuit consists of only a few discrete components, it boasts an elementary "digital display."

The amount I spent for materials (practically all were supplied by my modest junkbox) was rapidly paid off when I used my new gadget to sort a shoe box full of old, partly used electrolytic capacitors. The contents of the box had become the subject of more and more distrust over the years, and I was actually at the point of throwing the whole lot overboard.

The principle

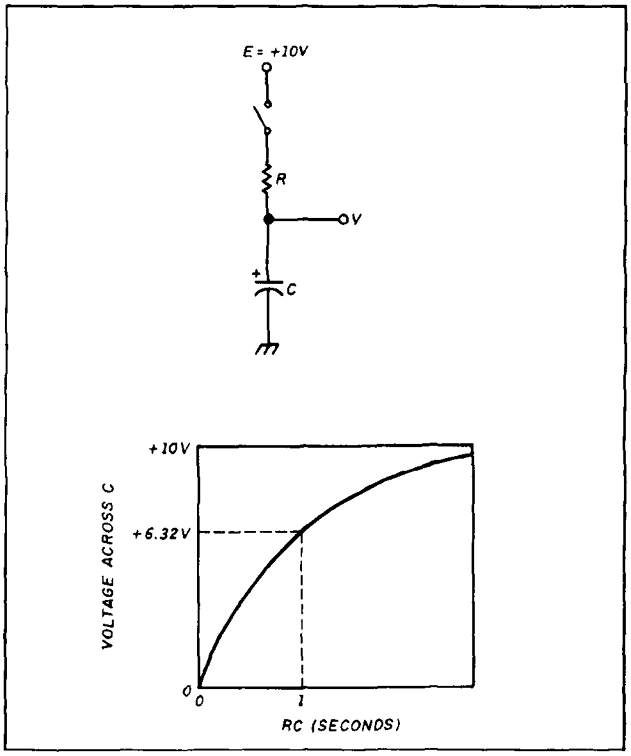
The principle of the microfarad counter is that of a capacitor charged through a resistor. When voltage is applied, the capacitor voltage builds up exponentially starting from zero, just as the textbooks specify. Something interesting occurs when the elapsed time (in seconds) becomes equal to R (in ohms) times C (in farads). You'll find the voltage across the capacitor has grown from zero to 63.2 percent of the supply voltage*.

If, for example, the supply voltage is 10 volts and R=1 meg (as shown in **Figure 1**), you reach a voltage of 6.32 across a 1-μF capacitor after 1 second. For an *n*-μF capacitor this would take *n* seconds. Thus, microfarads can be measured by counting seconds. It isn't too difficult to give the circuit a different "measuring range." If you make R = 100 k (ten times smaller), each second will represent 10 microfarads.

Putting this simple principle into practice is altogther something else. The voltmeter necessary to determine the 6.32 volts would unavoidably establish a bypass around the capacitor. This, in turn, would behave like a "leaky" capacitor. Because of the leakage, it would take more time to reach the threshold

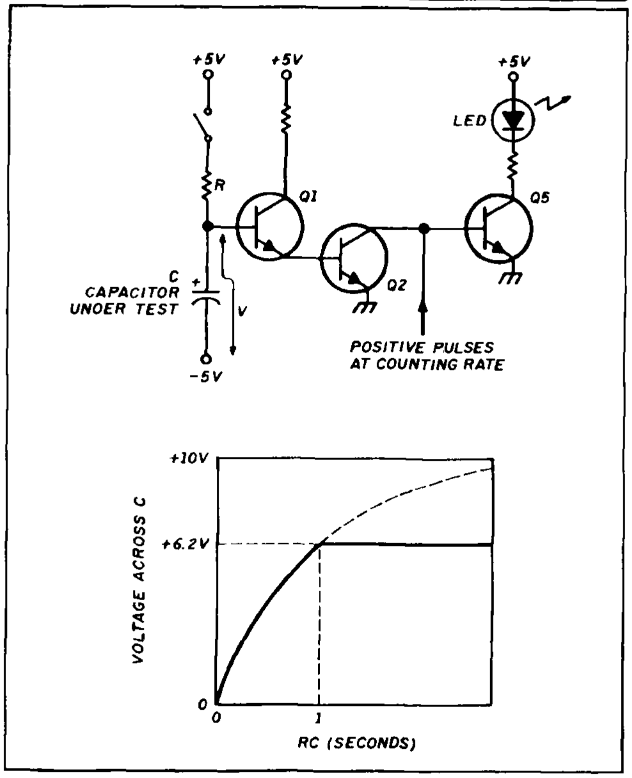
*$(1 - \frac{1}{e})$ times 100 percent, to be exact

FIGURE 1



Charging a capacitor through a resistor.

FIGURE 2



Principle of the Microfard Counter.

voltage, making the capacitor look larger than it actually is.

You're left with two choices. You can measure the voltage over R and then subtract it from the supply voltage. Or use a voltage indicator that, at least until the threshold is reached, looks like an electrical insulator. I found that the second option was the simplest. A wristwatch (or even a stopwatch) isn't the most practical time indicator in this case.

An improved counting system

There's a better system for counting the seconds. **Figure 2** shows how it's done. The stopwatch has been replaced by a light-emitting diode (LED) that produces light flashes for counting the charging time — or rather the microfarads. This counting mechanism is switched on as soon as the capacitor starts charging, and is switched off when the capacitor voltage reaches 6.2 volts (near enough to the ideal 6.32 volts, for the moment). Q2, the actual switching element, acts as a temporary short across the base of LED driver Q5.

The initial capacitor voltage is zero with the power supply connected. The base of Q1 begins by looking at −5 volts; Q1 blocks the base current of Q2 which, therefore, can't conduct. So while the capacitor starts charging, nothing prevents the LED from blinking.

The capacitor voltage grows, and when the Q1 base voltage arrives at +1.2 with respect to ground, both Q1 and Q2 start conducting because their base-emitter junctions now have the required 0.6 volt across them. The emitter-collector path of Q2 forms a short and the LED stops blinking. When this happens, the capacitor (situated between −5 volts at the bottom and +1.2 volts at the top) has been charged up to 6.2 volts, indicating that t=RC or: $C = \frac{t}{R}$.

Because the base voltage of Q1 remains virtually constant, the voltage across the capacitor doesn't rise, and remains stabilized at 6.2 volts. With the measurement completed, the current through R no longer flows into the capacitor; it finds its way through the transistors to ground instead. The microfarad meter isn't complete yet. As you saw before, the capacitor would cause a false reading if there's leakage. So for the measurement to make sense, it's essential to know whether the capacitor under test is leakproof.

Leakage detection

A conventional leakage-current meter would be quite something to design. Even leakage currents as low as several microamperes can be significant (remember they are DC), especially in smaller sized capacitors. The measured current should be totally independent of charge and discharge currents; this requires that a capacitor voltage remain untouched when the meter circuit is introduced. Fortunately, the concern when using the test box is whether the leakage is serious enough to spoil your measurements. You need not worry about the actual amount of current leaked.

I based my method on the following statement: *"Only if you extract the same amount of electricity from the capacitor as you've put in can you be sure that the capacitor isn't leaking."* In other words, if the capacitor after testing is discharged under the same conditions as it was charged, the charging and discharging processes should take the same amount of time.

You have to use an unusual technique to discharge the capacitor under the same conditions. Instead of being discharged passively across a parallel resistance (a method that would be unsuitable here as the process would follow a different portion of the characteristic), the capacitor is discharged actively when it's supplied with the same current in the opposite polarity.

The capacitor connections (charged to 6.2 volts as the result of the previous microfarad measurement) are reversed with a toggle switch. The positive side of the capacitor is now connected to a point that carries +1.2 volts and the negative side is connected to R (see **Figure 3**).

Initially, the base of Q1 sees a voltage of +1.2 volts in series with −6.2 volts, equaling −5 volts. The current through R discharges the capacitor. When the capacitor is fully discharged, the voltage across it is zero, and the base voltage of Q1 has arrived at +1.2 volts. This stops the process.

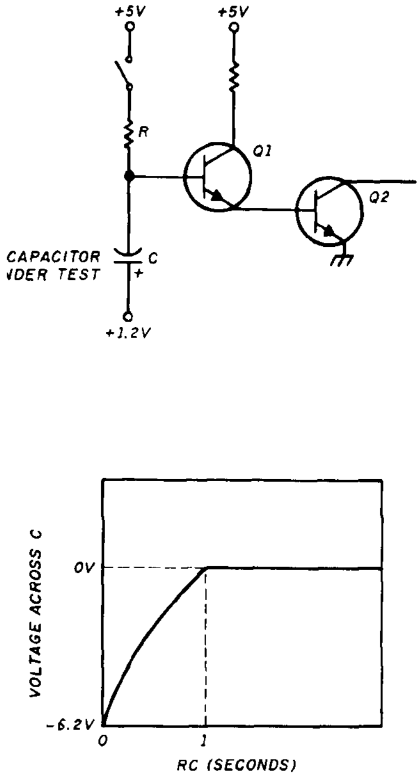
Q1 doesn't differentiate between charging or discharging, and the LED blinks in both cases. When measuring a healthy leak-proof capacitor, the LED blinks the same number of times for discharge as it does for charge. If there are fewer flashes, some of the electric charge was lost and you can conclude that the capacitor leaks.

During the entire charge-discharge cycle, the capacitor is never subjected to any voltage higher than 6.2 volts. The capacitor is left completely discharged after the capacity and leakage check.

The counter

It seemed appropriate to do some basic research before designing the blinking LED mechanism. I found that the once-per-second flashing rhythm would be exasperatingly slow. After doing some experimenting, I decided that a more suitable counting rate would be two flashes per second. The blinking is relatively fast, but not so fast that you risk losing count.

FIGURE 3



How the capacitor under test is discharged.

PARTS LIST

CAPACITORS

1 0.68 μF 25 volt tantalum
1 4.7 μF 25 volt electrolytic or tantalum

POTENTIOMETER

100 k Radio Shack RS271-220

RESISTORS (all resistors 1/4 watt)

R1—R5 see text, 5 percent
1 22 ohm
1 560 ohm
1 4.7 k
1 100 k
1 560 k
1 5.1 k
1 56 k

SEMICONDUCTORS

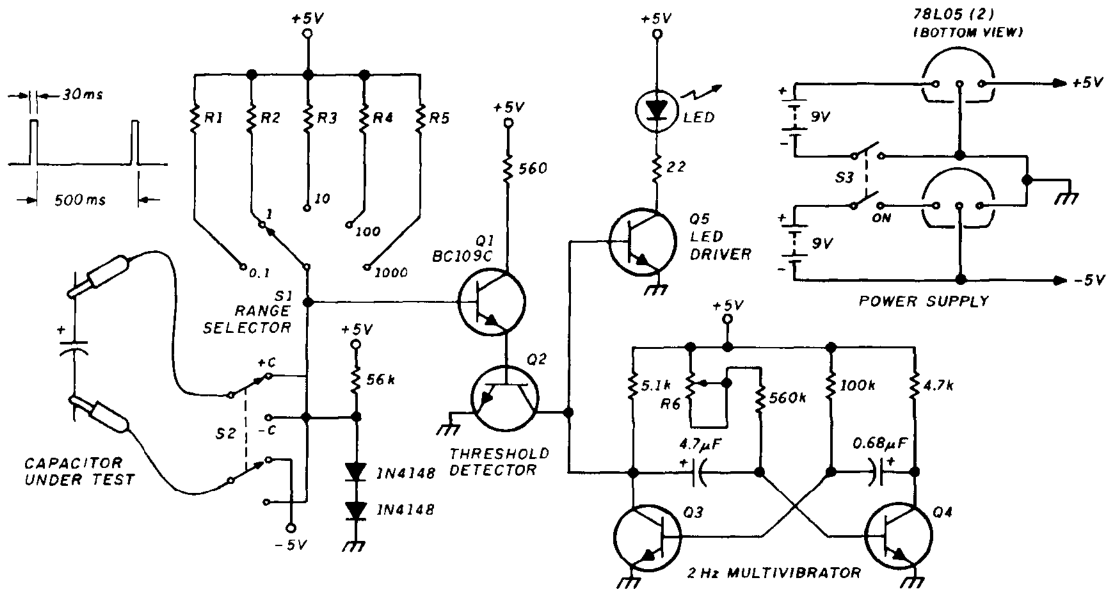
Q1—Q5 ECG 123AP or equivalent
2 78L05
2 1N4148 or equivalent
1 LED

MISCELLANEOUS

1 PCB FAR Circuits*
1 DPST miniature toggle switch
1 DPDT miniature toggle switch
1 SP5P rotary switch
2 9-volt battery connectors

All items obtainable from Radiokit, Box 973, Pelham, NH 03076, except as noted.
*18N640 Field Court, Dundee, IL 60118

FIGURE 4



Schematic diagram.

It's obvious that, with the LED flashing twice as fast, you have to correct the RC time to maintain the principle of one count per microfard. I compensated for this by changing R2 in **Figure 4** from 1 meg to 510 k. Although this is slightly more than the ideal of 0.5 meg, the difference takes care of the approximately 1.5-percent error in the 6.2-volt threshold (which ideally should have been 6.32 volts). I also had to consider the actual light/flash duration. I soon found out that a 50/50, on/off LED ratio isn't convenient for visual counting and that shrinking the length of the light pulse made counting easier. There are limits, of course — you can't make the length so small that visibility begins to suffer. Thirty ms seems to be a good compromise.

The drastic reduction in light/pulse length has more advantages. You can subject the LED to considerably more current than the 20 mA usually recommended. The 68 mA that flows through the LED (mainly determined by 22 ohms in the Q5 collector lead, and to a lesser extent by the collector resistor of Q3) visibly increases the brightness. Nevertheless, the average LED current still isn't more than a very reasonable 4 mA.

Calibration and accuracy

Calibration doesn't require a capacitor of any standard value. The accuracy of calibration depends entirely on the voltages (the output voltages of the 78LO5s, as well as the constant voltage drops over the diodes and transistor junctions), the resistors (R1 and R5 may be as accurate as desired), and the counting time. You can adjust the factor time by shorting the measuring leads (to make the LED flash) and by tuning R6 for exactly two counts per second.

The microfarad counter's total accuracy depends largely on the time you spend on measurement. If you measure a certain capacitor in 5 seconds, the unavoidable uncertainty of the last digit may cause an error of 10 percent. But if you're willing to spend almost a minute on the same measurement by switching to a lower range, and if the capacitor under test is leakproof, the digital error will be limited to 1 percent. In this respect, the elementary counting system of the microfard counter is in good company with other forms of digital displays, which also leave an uncertainty of at least plus or minus one digit.

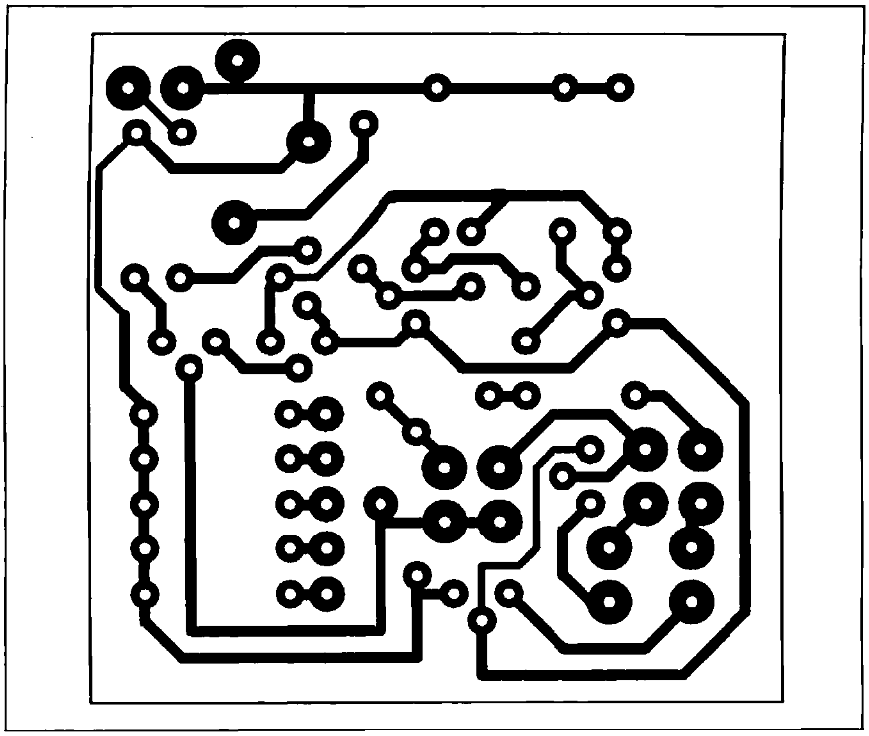
Other design considerations

I designed the circuit with low power supply requirements in mind. See **Figures 5** and **6** for the pc board layout and component placement guide. That's why I chose the LED as an indicator, rather than something like an acoustic bleeper. To ensure long-term battery consumption, it seemed necessary to use two batteries with a double-throw "power" switch. The 78L05 regulators appeared to provide the cheapest solution for maintaining reliable voltages.

The battery for positive supply must deliver an average current of 11.5 mA (it can be as high as 20 mA in the ×1000 position). The battery for the negative supply has to produce 3.5 mA; this means it should last longer.

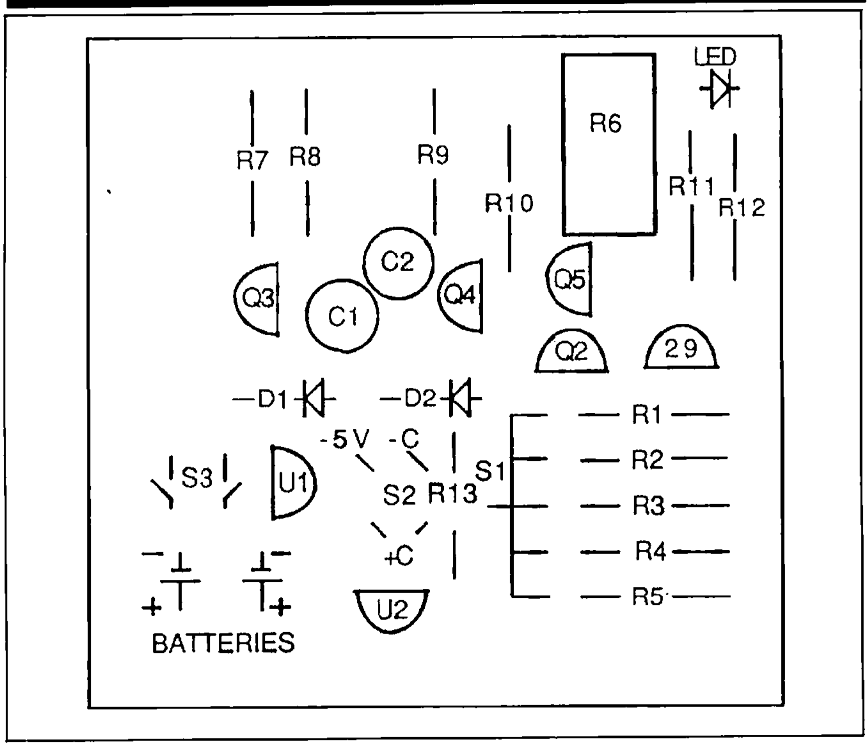
Use any common, low-power, silicone, NPN-type transistors. I used BC 237As from my junkbox. You must make an exception for Q1. A BC 109C works well because of its high beta at very low currents (in the "times 0.1" position the base current is only 0.8 μA!). If you can live without the times 0.1 range, you can use a more conventional transistor for Q1.

FIGURE 5



Foil side of pc board.

FIGURE 6



Component placement guide (component side).

Precautions

Some electrolytic capacitors have a maximum voltage rating lower than 6.5 volts. Don't measure these with the microfarad counter; they may be damaged. Capacitors with maximum voltage ratings at the other end of the scale also require a word of warning. When dealing with high-voltage capacitors, whether they are electrolytic, tantalum, or just ordinary paper-insulated type, you must always be aware of residual electric charges. They can develop *even if the capacitor has been entirely discharged by a complete, long-lasting, full short*. It's a good habit to short any capacitor (even if it's been lying around for some time) before doing something with it.

In any case, it seems advisable to put Q1 and Q2 where they can be easily replaced if disaster strikes.

Operating instructions

WARNING: Residual electric charge on high-voltage capacitors may damage the test instrument. Discharge the capacitor before connecting.

- Connect the capacitor, with the switch in position "−C." Observe correct polarity.
- Set the switch in position "+C." The LED will start flashing. Count the flashes until they stop. Each flash represents 1 μF (or 10 μF, 100 μF, and so on, depending on the position of the range switch).
- Switch to position "−C." The LED will start flashing again. Count the number of flashes until they stop. If the number is less than before, the capacitor is leaking current.

Observations

The use of electrolytic capacitors is usually regarded as an unavoidable evil. Some common problems you may experience with these caps are: limited life expectancy, exaggerated tolerance in value, and excessive leak current. After building my microfarad counter and using it to test a large variety of capacitors, I've found it necessary to reevaluate my opinion. Not only did there appear to be more leakproof electrolytic capacitors in my collection than I dared hope for, but their accuracy was generally much better than I expected. Most stayed within a tolerance of about ±15 percent. hr

Practically Speaking

Joe Carr, K4IPV

PART 1

HIGH-FREQUENCY DIPOLE ANTENNAS

An unfortunate myth arose in Amateur Radio circles some time ago. People came to believe that large antenna arrays were absolutely necessary for effective communications — especially for DX work. They tend to overlook basic, but effective, antennas that anyone can erect and make work. The simple *dipole* or *doublet* antenna is a case in point. This antenna is sometimes called the *Hertz* or *Hertzian* antenna, because radio pioneer Heinrich Hertz is said to have used it in his experiments.

The dipole is a balanced antenna with two quarter-wavelength radiators (**Figure 1**), making a total of a half wavelength. The antenna is usually installed horizontally, producing a corresponding horizontally polarized signal.

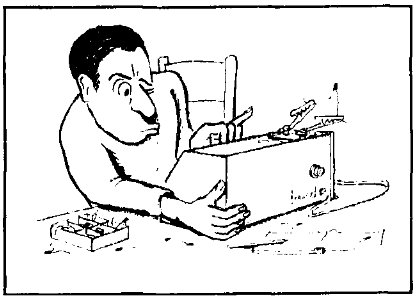
In its most common configuration (**Figure 1**), the dipole is supported at each end by rope and insulators. The rope supports are tied to trees, buildings, masts, or some combination of structures.

As I said before, the antenna length is a half wavelength. Remember that the physical length of the antenna and the theoretical electrical length often differ by about 5 percent. In free space, a half wavelength is found from:

$$L = \frac{492}{F_{MHz}} \text{ feet} \qquad \textbf{(1)}$$

Equation 1 gives you the physical length of a perfect, self-supporting antenna that's many wavelengths away from any object. But for real antennas, the length calculated using this equation is too long. The physical length is about 5 percent shorter because of the capacitive effects of the end insulators. A more nearly correct *approximation* (remember that word; it's important) of a half-wavelength antenna is:

$$L = \frac{468}{F_{MHz}} \text{ feet} \qquad \textbf{(2)}$$



Where:

L is the length of a half-wavelength radiator, in feet.

F_{MHz} is the operating frequency in megahertz.

Example 1

Calculate the approximate physical length for a half-wavelength dipole operating on a frequency of 7.25 MHz.

Solution:

$$L = \frac{468}{F_{MHz}} \text{ feet}$$

$$L = \frac{468}{7.25} \text{ feet} = 64.55 \text{ feet}$$

or, restated another way:

$L = 64$ *feet 6.6 inches*

Unfortunately, a lot of people accept **Equation 2** as a universal truth — perhaps because of books and articles on antennas that fail to tell it all. For example, you must consider *resonance*. An antenna acts like a complex RLC network. At some frequencies it will appear as an inductive reactance (X_l = +jX), and at others as a capacitive reactance (X_C = −jX). At a specific frequency the reactances are equal in magnitude but opposite in sign, so they cancel each other out: $X_l - X_C = 0$. At this frequency the impedance is purely resistive, and the antenna is resonant.

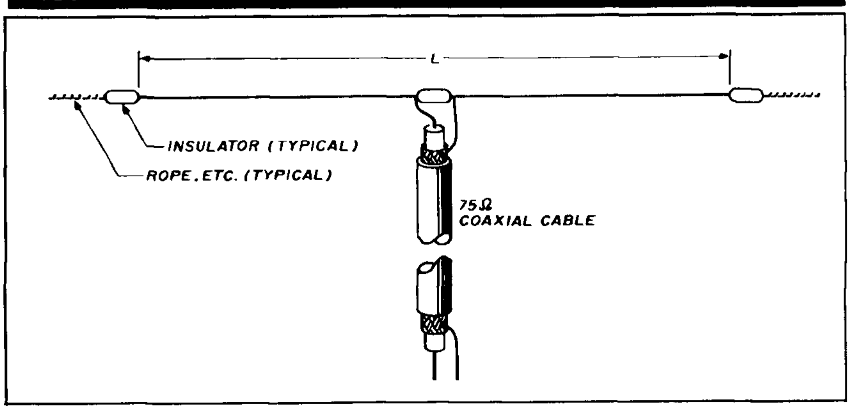
The goal in erecting a dipole is to make the antenna resonant at a frequency that's inside the band of interest — preferably the portion of the band most often used by your station. I'll discuss some of the implications of this later, but for now assume that you have to custom tailor the antenna length. Depending on several local factors (*among them nearby objects*, the antenna conductor's shape, and the conductor's length/diameter ratio), you may have to add or trim the length a bit to reach resonance.

The dipole feedpoint

The dipole is a half-wavelength, center-fed antenna. **Figure 2** shows the voltage (V), current (I), and impedance (Z) distributions along the length of the half-wavelength radiator element. The feedpoint voltage is at a minimum and the current is at a maximum, so you can assume that the feedpoint is a current "loop" or "antinode."

The impedance of the feedpoint at resonance is R_0 = V/I. R_0 is made up of two resistances. First there are ohmic losses that generate nothing but heat when the transmitter is turned on. These losses result because conduc-

FIGURE 1



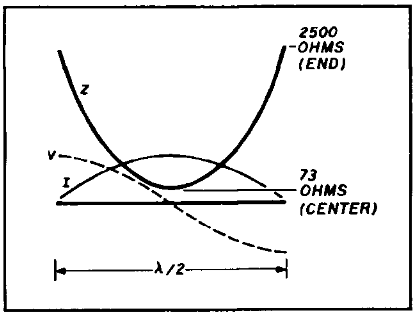
Standard coaxial cable fed half-wavelength dipole antenna.

tors have electrical resistance, and because electrical connections aren't perfect (even when properly soldered). Fortunately, in a well-made dipole these losses are almost negligible. The second contributor is the antenna's radiation resistance (R_r). This resistance is a hypothetical concept that accounts for the fact that the antenna radiates RF power. The radiation resistance is the fictional resistance that would dissipate the amount of power radiated away from the antenna.

For example, suppose you're using a large diameter conductor as an antenna, and it has negligible ohmic losses. If you apply 1,000 watts of RF power to the feedpoint, and measure a current of 3.7 A, what is the radiation resistance?

$$R_r = P/I^2$$
$$R_r = (1{,}000\ \text{watts})/(3.7)^2$$
$$R_r = 73\ \text{ohms}$$

FIGURE 2



Plot of current, voltage, and impedance distribution along half-wavelength dipole.

It's important to match the feedpoint impedance of an antenna to the transmission line impedance. Maximum power transfer always occurs when the source and load impedances (in any system) are matched. If some applied power isn't absorbed by the antenna (as happens in a mismatched system), then the unabsorbed portion is reflected back down the transmission line towards the transmitter. This results in standby waves, and the so-called standing wave ratio (SWR or VSWR).

Matching antenna feedpoint impedance may seem easy because the free space feedpoint impedance of a simple dipole is about 72 ohms. You'd think this would be a good match to 75-ohm coaxial cable. Unfortunately, the 72-ohm feedpoint impedance is almost a myth in practical situations. **Figure 3** shows a plot of approximate radiation resistance (R_r) versus height above ground (as measured in wavelengths). As before, you must deal in the approximations found in **Figure 3**; here the ambiguity is introduced by ground losses.

Despite the fact that **Figure 3** is based on approximations, you can see that radiation resistance varies from less than 10 to almost 100 ohms as a function of height. At heights of many wavelengths, this oscillation of the curve settles down to the free space impedance (72 ohms). At the higher frequencies it may be possible to install a dipole many wavelengths high. On the 2-meter band (144 to 148 MHz) one wavelength is around 6.5 feet (2 meters × 3.28 feet/meter), so it's relatively easy to achieve "many" wavelengths at reasonably attainable heights. In the 80-meter band (3.5 to 4.0 MHz), however, one wavelength is about 262 feet, so many wavelengths is a practical impossibility.

There are three tactics you can follow. The first is to ignore the problem altogether. In many installations, the height above ground will be such that the radiation resistance is close enough to present only a slight impedance mismatch to a standard coaxial cable. You'd calculate the VSWR as the ratio (among other ways):

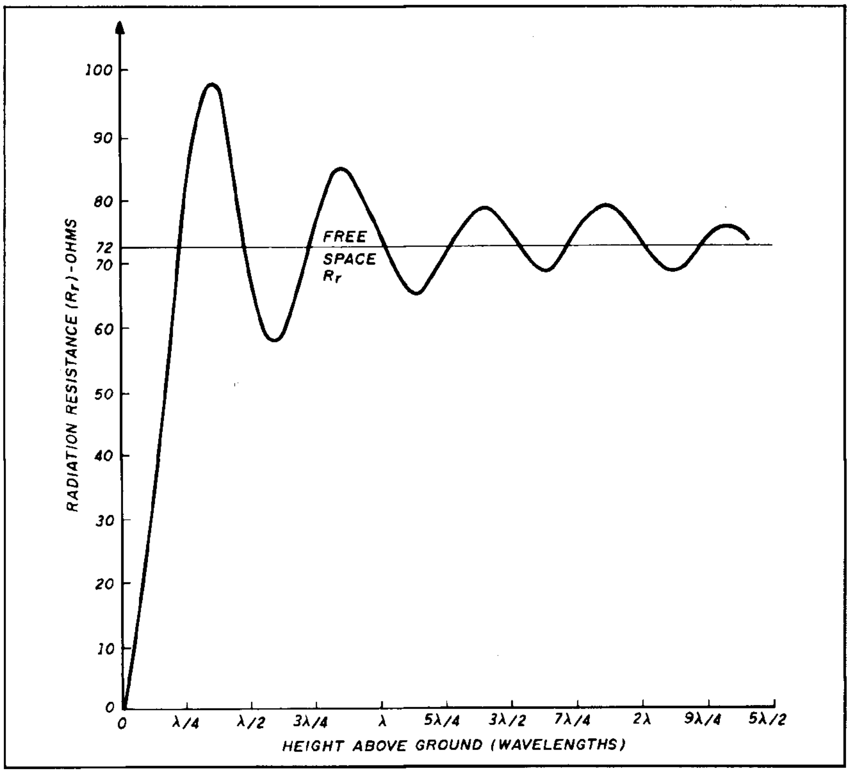
$Z_o > R_r$:
$$VSWR = Z_o/R_r \qquad \textbf{(3)}$$
$Z_o < R_r$:
$$VSWR = R_r/Z_o \qquad \textbf{(4)}$$

Where:
Z_o is the coaxial cable characteristic impedance.
R_r is the radiation resistance of the antenna.

Consider an antenna mounted at a height somewhat less than a quarter wavelength, with a radiation resistance of 60 ohms. While not recommended as good engineering practice, there are many practical reasons why it's necessary to install a dipole at less than optimum height. If so, what are the implications of feeding a 60-ohm antenna with either 52 or 75-ohm standard coaxial cable? Some calculations are revealing:

For 75-ohm coaxial cable:
$$VSWR = Z_o/R_r$$
$$VSWR = 75\ \text{ohms}/60\ \text{ohms} = 1.25{:}1$$

FIGURE 3



Feedpoint impedance versus height above ground.

For 52-ohm coaxial cable:

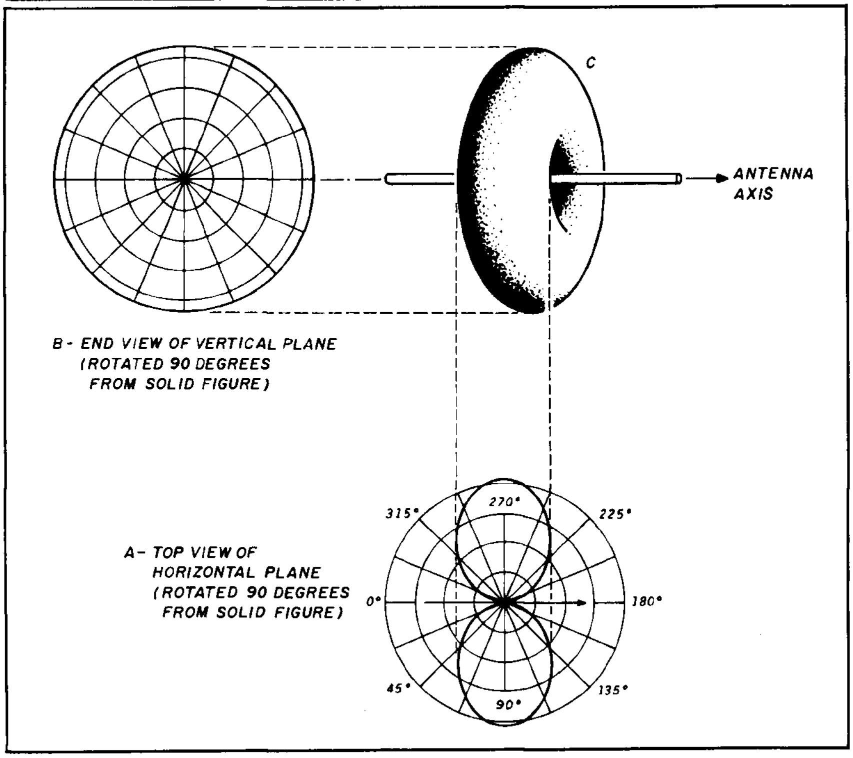
$$VSWR = R_r/Z_o$$
$$VSWR = 60\ ohms/52\ ohms = 1.15{:}1$$

In neither case is the VSWR created by the mismatch very significant.

The second approach is to mount the antenna at a convenient height and use an impedance-matching scheme to reduce the VSWR. You'll find information on suitable impedance-matching methods (including Q-sections, coaxial impedance transformers, and broadband RF transformers) in any good antenna textbook. Homebrew and commercial transformers can cover most impedance transformation tasks.

The third approach is to mount the antenna at a height (see **Figure 3**) where the expected radiation resistance crosses a standard coaxial cable characteristic impedance. The best height seems to be a half wavelength. The radiation resistance is close to the free space value of 72 ohms, and is a good match for 75-ohm coaxial cable (like RG-11/U or RG-59/U).

FIGURE 4



Radiation pattern of dipole in free space as seen from two planes (A and B), and three dimensionally (C).

The dipole radiation pattern

When discussing antennas I keep returning to the concepts of *directivity* and *gain*, which are actually different expressions of the same fundamental concept. Antenna theory recognizes a point of reference called the *isotropic radiator*. This device is a theoretical construct consisting of a spherical point source of omnidirectional RF radiation. It creates an ever-expanding sphere as the RF wave front propagates outward. Antenna gain is a measure of how the antenna focuses available power away from a spherical wave front in a limited number of directions (two, for a dipole). This is how the concepts of directivity and gain are related.

Always remember that *directivity and gain are specified in three dimensions*. Many times authors (including me) simplify the topic too much by publishing only part of the radiation pattern (i.e., azimuth aspect as seen from above). You, in turn, wind up with a pattern viewed from above that shows the directivity in the horizontal plane. A signal doesn't propagate away from an antenna in an infinitely thin sheet, as such presentations seem to imply, but has an elevation extent in addition to the azimuth extent. Proper antenna evaluation takes both horizontal and vertical plane patterns into consideration.

Figure 4 shows the radiation pattern of a dipole antenna in free space "in the round." When the horizontal plane is viewed from above (**Figure 4A**), the pattern is a "figure eight" that exhibits bidirectional radiation. Two main "lobes" contain the RF power from the transmitter, with sharp nulls of little or no power off the ends of the antenna axis. This is the classic dipole pattern published in most antenna books.

I've also shown the vertical plane pattern for a dipole antenna in free space. Note that the radiation pattern is circular when sliced in this aspect (**Figure 4B**). When the two patterns are combined, you see a three-dimensional doughnut-shaped pattern (**Figure 4C**) that most nearly approximates the true pattern of an unobstructed dipole in free space.

When a dipole antenna is installed close to the ground and not in free space, as is the case at most stations, the pattern is distorted from that of **Figure 4**. You must take two effects into consideration. First and most important is that the signal from the antenna is reflected from the surface and bounces back into space. This signal will be phase shifted by both the reflection and the time required for the transit to occur. At points where the reflected wave combines in phase with the radiated signal, the signal is reinforced; in places where it combines out of phase, the signal is attenuated. Thus the reflection of the signal from the ground alters the pattern from the antenna. The second factor to consider is that the ground is lossy, so not all of the signal is reflected; some of it heats the ground underneath the antenna. Consequently, the signal is attenuated at greater than inverse square law, further altering the expected pattern.

Figure 5 shows patterns typical of dipole antennas installed close to ground. The views in this illustration correspond to **Figure 4B** in that they are looking at the vertical plane from a line along the antenna axis. The antenna is represented by "R" in each case shown. **Figure 5A** shows the pattern for a dipole installed at one-eighth wavelength above ground. For this antenna, most of the RF energy is radiated almost straight up (now very useful). This type of antenna is basically limited to groundwave and very short skip (when availa-

ble). The second case (**Figure 5B**) shows the pattern when the antenna is a quarter wavelength above the ground. Here the pattern is flattened, but still shows considerable vertically reflected energy (where it is useless). Now look at the pattern obtained when the antenna is installed a half wavelength above the surface. In **Figure 5C**, the pattern is best for long distance work because energy is redirected away from the vertical into lobes at relatively shallow angles.

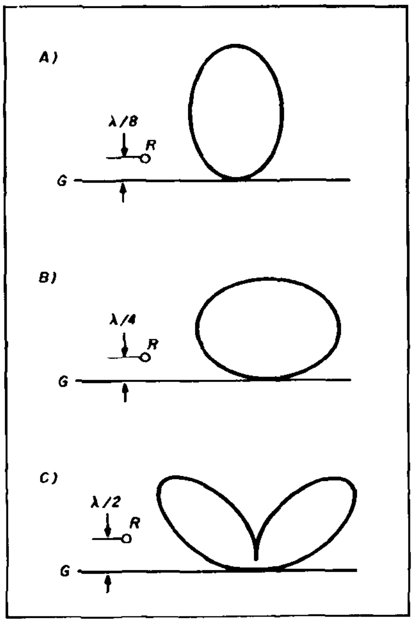
Dipole construction and installation techniques

According to "conventional wisdom," the ideal dipole antenna should be installed at a very high altitude where its performance resembles the free space model. Unfortunately, complying with conventional wisdom is impossible — even for antennas in the higher end of the HF spectrum. Given that the dipole feedpoint impedance is a good match for 75-ohm coaxial cable, and that the pattern is ideal for long distance work when the antenna is installed at a height of a half wavelength above the surface, it's a good idea to try installing the antenna at that height.

Building and installing simple dipoles isn't terribly difficult. **Figure 6** shows the method for building the antenna. First, cut the wire radiator elements to the approximate length indicated by **Equation 2** plus an additional 12 to 24 inches; each element will finally be a quarter wavelength long. The wire can be either hard-drawn copper wire or Copperweld®. The latter is a special tough-service steel core antenna wire coated with copper. The RF resistance of this wire at frequencies above 1 MHz is the same as that of solid copper wire because of the "skin effect" (alternating currents like RF flow on the outer surface of the conductor only). At 160 meters the skin effect depth is only 50 microns (2 mils), while at 10 meters it's only 12 microns (0.5 mils). This means you have the advantage of copper conductivity along with the strength of steel wire.

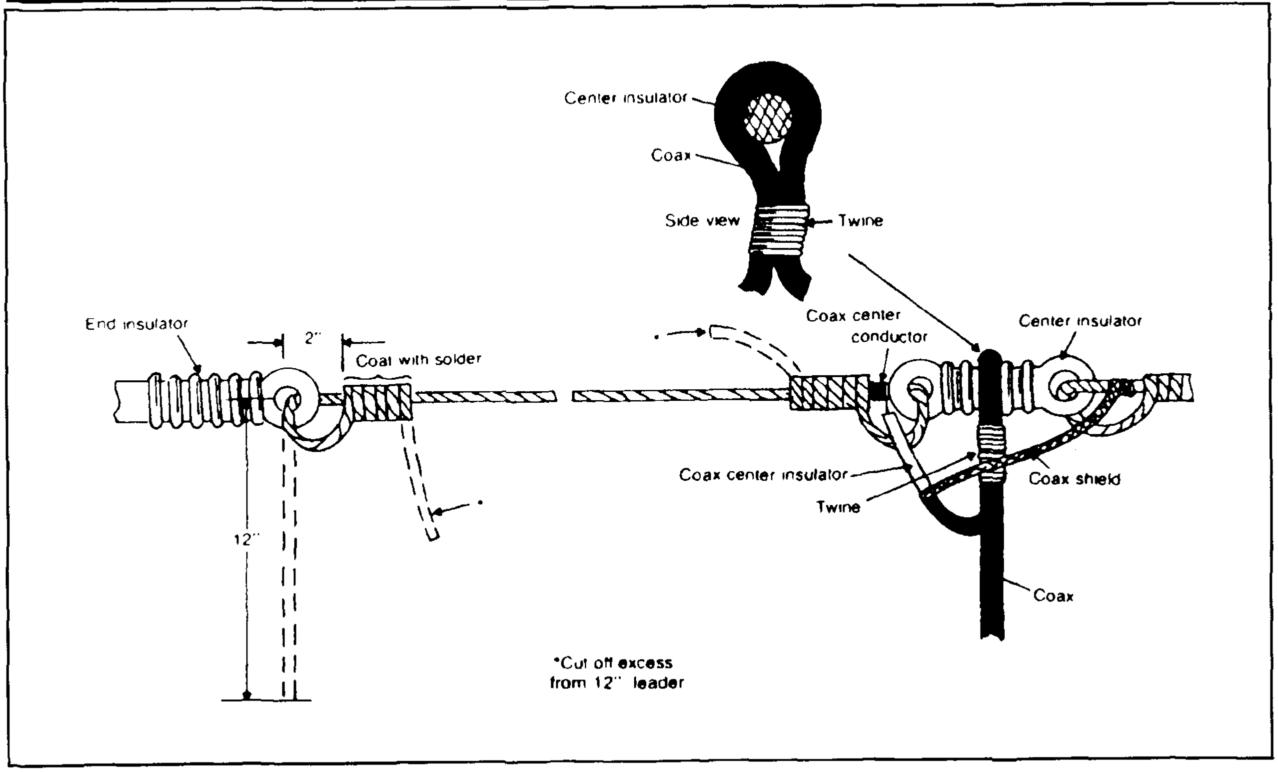
You'll need two end insulators, and both are assembled in the same way. Pass the wire through the hole in the insulator (see **Figure 6**) to a length of about 12 inches. Wrap the wire back on itself and wind it around the portion of the wire that's left on the other side of the insulator. Make this a permanent

FIGURE 5



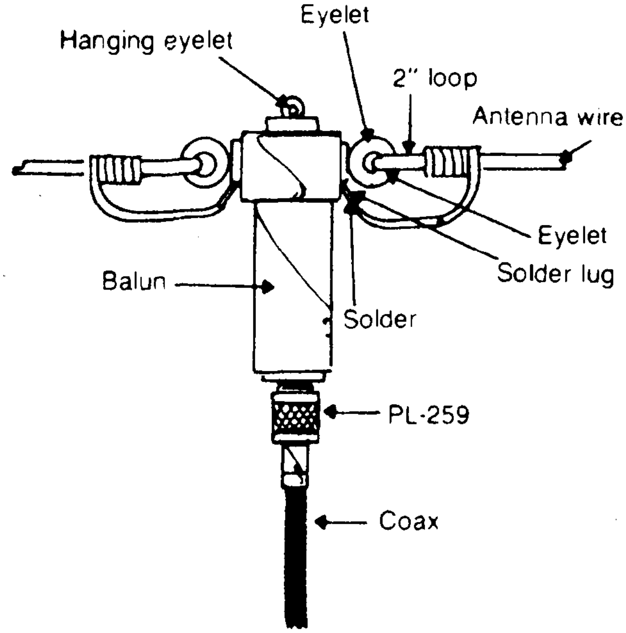
Vertical aspect radiation pattern of dipole close to earth's surface: (A) 1/8-wavelength, (B) 1/4-wavelength, and (C) 12/2-wavelength.

FIGURE 6



Construction details of dipole antenna (from *TAB Handbook of Radio Communications* by J.J. Carr).

FIGURE 7



Use of a 1:1 balun transformer at the feedpoint (from *TAB Handbook of Radio Communications* by *J.J. Carr*).

connection by soldering it and clipping off the excess wire. The solder *won't* provide mechanical strength. Its purpose is to make a good electrical connection in the presence of corrosion.

Fix the antenna wires to the center insulator in the same way, unless you plan to use one of the special center insulators now on the market. Make these connections temporary until after you've tuned and tested the antenna. You may have to either lengthen or shorten the radiators when tuning your dipole.

Connect the transmission line (usually coaxial cable) to the antenna wire at the center insulator as shown. Attach the center conductor to one radiator element and the shield of the coax to the other. You need to provide strain relief for the coaxial cable; if you don't the cable will break after only a short period of service. The easiest strain relief method is shown in **Figure 6**. Simply wrap the cable once around the insulator and tie it off with twine. Some commercial center insulators offer a strain relief hole or other mechanism. Many people prefer to use a 1:1 balun transformer at the dipole's feedpoint (see **Figure 7**). The transformer has a 1:1 impedance ratio, so it doesn't provide any matching. Instead, it's said to balance the currents flowing in the two radiators, and prevent radiation from reaching the feedline. While this claim has been controversial for some time, and the issue is still not resolved, the best evidence suggests that the pattern of a dipole close to ground is most nearly like the ideal pattern if a 1:1 balun transformer is used at the feedpoint. In **Figure 7** the balun transformer also acts as the center insulator, so no other arrangement is needed.

Next month...

This month I looked at the basic resonant dipole. In part 2, I'll discuss tuning methods for the standard dipole, and some additional variations on the dipole theme.

Digitar TWR-3 Weather Station

Like most New Englanders, I'm very interested in the weather. I wanted to own weather instruments that would provide good data, but found the cost of most systems prohibitive because of fancy features.

The Digitar series of handheld weather stations meet my standards. The TWR-3, advertised as the world's smallest computer weather station, "packs a wallop" of information including wind speed (3 to 250 mph), wind direction (in degrees, two scales), wind gust record, temperature (−70 to +270 degrees F), high/low temperature record, and has an optional rainfall gauge at extra cost.

The TWR-3 reads in English or metric units and can be programmed to scan through its various functions. It operates on house current, 12-volt DC supply, or its own internal battery support. I installed it easily in less than an hour.

The model TWR-3 is made by Magnaphase Industries, Inc., and is available from Azimuth Weather Star, 11845 W. Olympic Blvd., Suite 1100, Los Angeles, California 90064, for $159.95.

de N1GCF

Circle #301 on Reader Service Card.

Mobile data unit

The TEMPO MPP1 TNC/printer combination is a compact unit for mobile or portable use. The processor portion of the unit is compatible with TAPR TNC 2 and makes use of the complete command set. With 32K ROM and 32K RAM it's possible to:

- store and print all messages received while operating.
- store all messages for printing within the ROM unit.
- store messages to a selected terminal for immediate or delayed printing.

Specifications:

Protocol
AX.25 level 2

Modem
AFSK (1200-2200 Hz)

Processor
Z80 software compatible

Memories
ROM 32K, RAM 32K (lithium battery backup)

Communication speed
1200 bps (radio link)

Terminal data rate
120 bps (300 to 9600 selectable), RS 232C compatible

Power requirement
13.8 volts DC at 700 mA

Printer
Thermal Series dot, 40 characters/line, 24 characters/second

Paper
Thermal, 3-1/8 inch paper tape

Controls
ON/OFF, manual/auto select, paper feed

Indicators
POWER on, Tx, Rx, STAtus, CONnected, PTR

Connections Radio interface (5 pin)
Terminal interface (DB-9)
Power DC (2 pin)

The mobile data terminal is shipped complete with cables for connections to a transceiver, computer serial port (RS 232C), and DC power source. Also included are the installation and user's manual and a spare roll of thermal paper. An AC Adapter for supplying DC power from the 117 VAC line and a technical manual complete with schematic are optional. The technical manual is recommended for understanding the circuitry. It's very helpful if you're just getting started in packet, as the installation and user's manual is brief.

Instructions for connecting the unit to your VHF transceiver and computer are straightforward and well documented. You'll have to provide the proper radio and computer plugs to match your equipment, but the MPP1s are already mounted on their cables with the other ends left as flying leads.

I tested the unit with three different transceivers, ICOM-25A, Kenwood TM-221A, and Kenwood TM-621A. The ICOM and Kenwood units had different connections, so I made an adapter to interchange the units easily. I also used two different computers, an IBM PC-XT and a Radio Shack Model 100 (lap top) unit.

Initialization of the MPP1 was easy and well outlined in the manual provided. You must load the terminal's RAM with the proper defaults and your callsign on initial setup. Then your terminal is ready for base or remote use.

I did base station testing with the transceivers connected to a stacked pair of Yagis. I made contacts with stations as far away as Montreal, Canada by using digipeaters. The unit was very tolerant of audio level variations, and did not drop messages during periods of fading or when the audio level was intentionally varied using the gain control. My mobile testing included traveling a route that passed through known weak signal and multipath areas. I copied a couple of bulletin boards without fault and left messages for other users.

This unit is ideal for emergency communications. Amateurs involved in ARES activities should consider it for remote operation. The TNC portion of the unit is a complete processor in itself and directly controls the printer; it can be used as a receive only monitor for messages, with printout activated when convenient.

My only difficulties were due to "cockpit errors" because I have limited packet experience. It's well worth the extra cost to order the technical manual.

I'd like to thank Bill Burden, WB1BRE, for riding copilot and operator during the mobile testing.

The MPP1 sells for $395 and is available from HENRY RADIO, 2050 S. Bundy Drive, Los Angeles, California 90025.

de WA1TKH

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Cushcraft 124WB-element, 2-Meter boomer antenna

Here's a neat compact antenna that can be used in a number of applications. It's perfect for packing to the top of a mountain or high hill; fire it up on 2-meter SSB, or use it for repeater DXing. Apartment dwellers can sneak this antenna into almost any location and get the benefit of directivity and gain. For me, it simplified connecting into the local DX-spotting packet network.

In the past, I had been using either a horizontally polarized antenna or a 5/8-wave vertical. Unfortunately, anytime I rotated the triband beam, I lost the packet network. There was also a 20-dB signal loss between my *horizontal* beam and the packet cluster's *vertically* polarized antenna. The vertical, well, it never worked right.

Cushcraft's 4-element boomer is elegant in it's simplicity. Construction is straightforward and takes just a few minutes. Because of the small size, this antenna can be shoehorned into almost any location.

The 124WB will tune 144-148 MHz with a less than 2:1 SWR. Cushcraft rates the forward gain at 10.2 dBd, with a front-to-back ratio of 19 dB. Assembled wind area is less than 6 inches and the antenna weighs less than three pounds. The retail price is $60. If you want more gain, stacking instructions are included.

From the top of the tower to the attic (where mine is), installation is not a problem and takes just a few minutes. Later this spring, I'll move the antenna to the tower to gain a few additional vertical feet. Now that I'm using the 124WB, I can get into the packet network with ease. The forward gain and directivity gives me a better chance at connecting into the network, even during its busy times.

For further information contact Cushcraft Corp., P.O. Box 4680, Manchester, New Hampshire 03108.

de N1ACH

Circle #303 on Reader Service Card.

Ultra-compact IC-725 HF transceiver

ICOM has introduced a new compact IC-725 HF transceiver. The all-mode IC-725 features:

- USB/LSB/CW transmitting and receiving. AM receiving. Optional module no. UI-7 for FM transmit/receive and AM transmit
- 26 tunable memories with band stacking registers
- DDS (Direct Digital Synthesizer) system
- Built-in AH-3 controller. Optional AH-3 automatic antenna tuner available.
- Three scanning systems: programmable, memory, and selected mode scan
- Priority watch.
- 105-dB dynamic range receiver.
- 160 through 10-meter operation. Short-wave reception from 30 kHz to 33 MHz.

Other features include: Panel-selectable RF preamp and attenuator, dual VFOs, noise blanker, RIT, semi-break in CW, selectable AGC, full-duty cycle, and optional narrow CW filter.

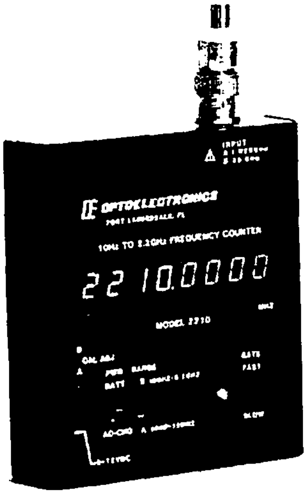
The suggested retail price of the IC-725 is $949.

For more information contact ICOM America, Inc., 2380 116th Ave. N.E., PO Box C-90029, Bellevue, Washington 98009-9029.

Circle #304 on Reader Service Card.

Handheld frequency counter

Optoelectronics, Inc. introduces its new hand-held frequency counter model 2210. It has low frequency coverage down to 10 Hz and microwave coverage up over 2.2 GHz. The counter runs on internal NiCd batteries and comes with a metal cabinet and precision quartz timebase oscillators. A full line of accessories includes antennas, probes, and carry case.



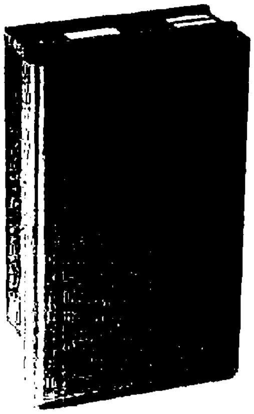
Input sensitivity is less than 10 mV from 10 Hz to 2 GHz, 3 mV is typical. Accuracy is 1 PPM with temperature compensated crystal oscillators. Resolution is 1 Hz below and 100 Hz above 12 MHz. A full 16-hour recharge yields 2 hours of battery operation. Use an AC adapter/charger to operate when recharging.

The model 2210 sells for $189 complete with NiCd batteries and charger. The model TA-100S telescoping whip antenna is $12 and the vinyl carry case is $10. For more information contact Optoelectronics, Inc., 5821 N.E. 14th Avenue, Fort Lauderdale, Florida 33334.

Circle #305 on Reader Service Card.

Super performance battery packs

Periphex, Inc. offers battery packs that are compatible with the following Yaesu radios: FT-727R, 109RH, 209R/RH, 709R, 103R, 203R and 703R.



The FNB-4SH, 12-volt 1-Ah battery is double the capacity of the original FNB-4/4A battery pack, and is compatible with the Yaesu NC-15 base charger. The FNB-4SH is priced at $71.

The FNB-4SL, 12-volt 0.75-Ah battery has 150 percent of the capacity of the original FNB4/4A battery pack, and is also compatible with the Yaesu NC-15 base charger, NC-18B, and PA-3 trickle charger. This pack is priced at $65.

The FNB-3S, 9.6-volt 1.2-Ah battery is almost triple the capacity of the original FNB-3/3A battery, and is designed as a long-life battery pack. The FNB-3S is completely compatible with the Yaesu NC 15 base charger, NC-18B, and PA-3 trickle charger. The price of the FNB-3S is $60.

All battery packs include overcharge, over temperature, short-circuit protection, and a 1-year warranty.

For more information contact Periphex, Inc., 149 Palmer Road, Southbury, Connecticut 06488.

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New free catalog from MFJ

MFJ Enterprises, Inc. announces their new full-line 16-page 1989 MFJ *Amateur Radio Accessories Catalog.*

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Macintosh WeFaxWorks

WeFaxWorks is a program for the Apple Macintosh computer that allows reception of weather maps and charts on a standard Macintosh using Kantronics' KAM, all-mode interface. During live reception, the screen scrolls automatically. Synchronization is simple; point the mouse at the sync mark and click once. This causes the received and displayed signal to be aligned with the left edge of the Macintosh screen.

The entire picture is saved into a buffer as it's being received. Once you exit the receive mode, you can select the buffer display, and the captured picture will appear on the screen.

The buffer contents can be saved to disk by choosing "Save..." from the File menu, and a saved WeFaxWorks map can be recalled from disk with the "View File..." selection. The buffer contents are erased when you enter the "Receive Live" mode, or when a map is recalled from the disk.

Maps are printed with MacPaint format files. The portion you want to print is brought to the screen using the Display Buffer mode and scroll bar. These files are in MacPaint format and can be opened, touched up, and printed with MacPaint.

For more information contact Kantronics at 1202 E. 23rd Street, Lawrence, Kansas 66046.

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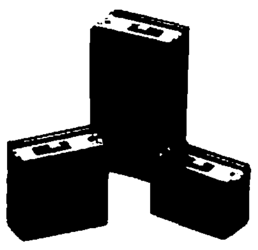

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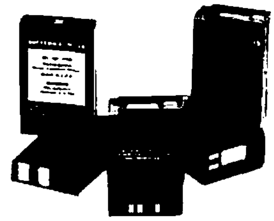

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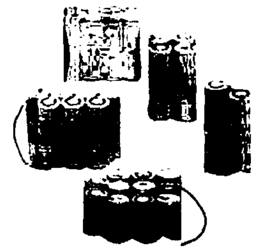

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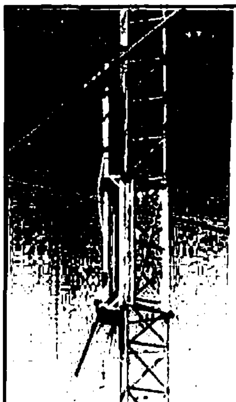

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SO239AM UHF chassis mt receptacle,Amphenol	.89
UG88C BNC plug RG58, 223, 142	1.45

GROUND STRAP-GROUND WIRE (per ft)

GS38 3/8" tinned copper braid	.40
GS12 1/2" tinned copper braid	.50
GS200 1-1/2" heavy tinned copper braid	2.00
HW06 6ga insulated stranded wire	.39
AW14 14ga stranded Antenna wire CCS	.14

Prices do not include shipping, $3 minimum, Visa/Mastercard $30 min, COD add $3.00

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Tell 'em you saw it in HAM RADIO!

DX Forecaster

Garth Stonehocker, KØRYW

1988 PROPAGATION SUMMARY

September 1986 was definitely the month of sunspot minimum, with the smoothed sunspot number (SSN) equal to 12.3. That makes 1988 the second year of solar cycle 22. The solar flux minimum of 67.6 occurred in June 1986, but September of that year also brought the smoothed value minimum of 72.9, along with the sunspot minimum. In 1988, the sunspot number started out at 58 and ended at about 137 while the solar flux started at 108 and ended at 200. These numbers made it the steepest climbing year of the cycle as SSN and solar flux are expected to taper off to a maximum of 185 for SSN and 225 for the solar flux near the end of 1989. While the 1987 values were slightly above the highest in cycle 19, the 1988 values' slope crossed cycle 19's, so these forecast values are probably reasonable.

In 1988, midlatitude noontime maximum usable frequencies (MUFs) monthly median increased from 19 to 27 MHz for a 3000-km hop. The increase wasn't linear throughout the year because the summer F2 layer was 15 percent less than it was the rest of the time, with the equinoxal periods having the highest MUF. This increase in MUF levels off for SSNs greater than 150, as does the solar flux. Most solar flux to SSN conversion formulas don't take this into account. This also shows how the MUF follows solar flux values above 150 instead of the SSN; this will be the condition during 1989. The MUF formula for monthly medians is MUF = 2.65 × (0.0165 × SSN + 8.4).

During 1988, propagation was affected adversely by several periods of geophysical events. In March I discussed how to forecast propagation conditions a day or two in advance using the trend in solar flux and geomagnetic A values. Now I'd like to show how MUFs correlated with flux and A indexes during several large events in 1988. The first occurred on February 20th during a decreasing solar flux (107 to 102). A small solar flare started a high-latitude geomagnetic event which spread down to the midlatitudes by the 22nd. The A value went to 67 and decreased MUFs 48 percent to 10 MHz. The MUFs were 25 percent on the 23rd, 19 percent on the 24th, and 15 percent on the 25th before recovering. On March 25th, a small flare was probably the cause of a polar cap absorption and small geomagnetic disturbance. The MUF increased 33 percent over the first two days, then decreased 17 percent for the next two. The solar flux had just increased 7 units, but was level during the disturbance. A corresponding increase in MUF occasionally occurs as it did here, when the solar flux is on the increase or if the disturbance starts as the sun is rising on the propagation path. The next notable event began with a gradual disturbance of unknown cause on April 3rd through the 7th, which dropped the MUFs 46 percent during an A of 57. The solar flux was decreasing from 128 to 115.

Another large disturbance (A index = 63) began gradually near the end of May 5th and lasted one day. The MUF decreased 66 percent before it was over. The solar flux decreased 5 units during this period. The last significant event affecting propagation was on October 10th, caused by a small solar flare and solar flux burst. The geomagnetic disturbance measured 57 on the A index and the MUF decreased nearly 40 percent as the solar flux was going down. You'll notice that most of these events happened as the solar flux was decreasing and that the MUF decrease was greater at those times than it was during those disturbances when the solar flux was increasing. The MUF decrease averages 2 percent per A unit when the solar flux is decreasing, as opposed to a 0.8-percent MUF decrease per A unit when the solar flux is level or increasing. The solar flux factor for the beginning of 1988 was 1 percent MUF change per unit of solar flux; later in the year it increased to 2 units of solar flux for a 1-percent MUF change.

You can use these factors during this phase of the SSN cycle to predict the best band for daily operation. There are more bands to jump to now and in July. Good luck!

Last-minute forecast

The higher frequency bands (10 to 30 meters) are expected to have the best openings the first and the last week and a half of May. These openings may include some 6-meter long skip when WWV solar flux values indicate the very peak of the 27-day solar cycle. Transequatorial (TE) single long-hop openings will probably be available towards the evening early in May; these openings are scarce during June, July, and August. Periods of disturbance around the 5th and 13th may enhance the possibility of TE openings. Another expected disturbance date, the 22nd, may come too late to help TE but may affect east-west paths on the lower bands. These lower bands should be best the second and third weeks of the month, when the solar flux is expected to be at minimum. The higher minimums restrict daytime DX distance from weak signals.

The full moon occurs on the 20th; the lunar perigee is on the 3rd and 31st. An Aquarid meteor shower (for meteor scatter and meteor burst DXers) peaks between May 4th and 6th, with rates of 10 and 25 per hour for the northern and southern hemispheres, respectively.

Band-by-band summary

Ten, 12, 15, 17 and 20 meters will support DX propagation from most areas of the world during daylight hours and into the evening, with long skip out to 2000 miles (3500 km) per hop. Signals on the upper three bands will be strongest from the southern countries and occur near local noon.

MAY

WESTERN USA

GMT	PDT	N (ASIA FAR EAST)	NE (EUROPE)	E (S. AFRICA)	SE (S. AMERICA)	S (ANTARCTICA)	SW (NEW ZEALAND)	W (OCEANIA AUSTRALIA)	NW (JAPAN)
0000	5:00	12	20	15	10	12	10	10	12*
0100	6:00	12	20	15	10	12	10	10	10
0200	7:00	12*	20	20	12	12	10	10	10
0300	8:00	12	20	20	12	15	10	10	10
0400	9:00	12	20	20	12	20	10	10	12
0500	10:00	15	20*	12	15	20	10	10	12
0600	11:00	15	20	12*	15	20	10	10	12
0700	12:00	15	20	12	15	20	10	10	15
0800	1:00	20	20	12	20	20	12	12	15
0900	2:00	20	20	15	20	20	12	12	15
1000	3:00	20	20	15	20	20	12	15	20
1100	4:00	20	15	12	20	30	15	15	20
1200	5:00	15	15	12	15	30	15	15	30
1300	6:00	15	15	10	12	30	15	20	30
1400	7:00	15	12	10	12	30	20	20	20
1500	8:00	15	12	10	10	30	20	20	20
1600	9:00	15	10	10	10	30	20	20	20
1700	10:00	20	10	10	10	15	12	20	20
1800	11:00	20	10	10	10	15	12	20	20
1900	12:00	20	12	10	10	12	10	12	15
2000	1:00	20	12	10	10	12	10	10	12
2100	2:00	15	15	12	10	12	10	10	12
2200	3:00	12	15	12	10	12*	10	10	12
2300	4:00	12	20	15	10	12	10	10	10

MID USA

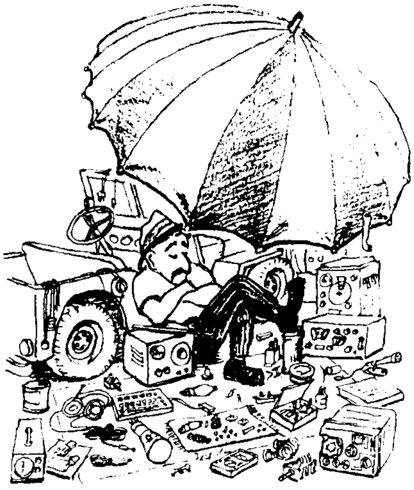
MDT	N (ASIA FAR EAST)	NE (EUROPE)	E (S. AFRICA)	SE (S. AMERICA)	S (ANTARCTICA)	SW (NEW ZEALAND)	W (OCEANIA AUSTRALIA)	NW (JAPAN)	CDT
6:00	15	20	15	10	12	10	10	10	7:00
7:00	15	20	15	10	12	10	10	10	8:00
8:00	15	20	20	12	15	10	10	12	9:00
9:00	15	20	20	12	20	10	10	12	10:00
10:00	15	20	20	12	20	10	10	12	11:00
11:00	15	20	15	15	20	10	10	15	12:00
12:00	20	20	15	15	20	10	10	15	1:00
1:00	20	20	15	20	20	10	12	15	2:00
2:00	20	20	15	20	20	12	12	20	3:00
3:00	20	20	15	20	20	12	15	20	4:00
4:00	15	20	12	20	30	15	15	30	5:00
5:00	15	20	12	15	30	15	15	20	6:00
6:00	15	15	10	12	30	15	20	20	7:00
7:00	12	15	10	12	30	20	20	15	8:00
8:00	12	15	10	10	30	20	20	15	9:00
9:00	12*	12	10	10	30	20	20	20	10:00
10:00	12	12	10	10	30	12	20	20	11:00
11:00	12	10	10	10	20	12	20	30	12:00
12:00	15	10	10	10	15	12	20	15	1:00
1:00	15	12	10	10	15	10	12	15	2:00
2:00	20	12	10	10	12	10	10	15	3:00
3:00	20	15	12	10	12	10	10	12	4:00
4:00	20	15	12	10	12	10	10	12	5:00
5:00	15	20	15	10	12	10	10	10	6:00

EASTERN USA

EDT	N (ASIA FAR EAST)	NE (EUROPE)	E (S. AFRICA)	SE (CARIBBEAN S. AMERICA)	S (ANTARCTICA)	SW (NEW ZEALAND)	W (OCEANIA AUSTRALIA)	NW (JAPAN)
8:00	15	20	15	10	15	10	10	10
9:00	15	20	15	10	15	10	10	12
10:00	15	20	20	12	20	10	10	12
11:00	15	20	20	12	20	10	10	12
12:00	20	20	20	12	20	10	10	15
1:00	20	20	15	15	20	10	10	15
2:00	20	20	15	15	20	10	12	20
3:00	20	20	15	20	20	12	12	30
4:00	15	20	20*	20	30	12	15	20
5:00	15	20	12	20	30	15	15	20
6:00	15	15	12	15	30	15	15	15
7:00	12	15	10	12	30	15	20	15
8:00	12	12	10	12	30	15	20	15
9:00	12*	12	10	10	30	20	20	15
10:00	12	12	10	10	30	20	20	20
11:00	12	10	10	10	30	20	20	20
12:00	15	10	10	10	20	20	20	30
1:00	15	12	10	10	15	12	20	15
2:00	20	12	10	10	15	12	20	15
3:00	20	12	10	10	15	10	12	15
4:00	30	12	10	10	12	10	10	12
5:00	20	15	12	10	12	10	10	12
6:00	15	15	12	10	12	10	10	10
7:00	15	15	15	10	12	10	10	10

The propagation direction will follow the sun across the sky. It will be to the east in the morning, the south at midday, and the west in the evening. Sporadic-E short skip will be available at local noon on some days toward the end of the month.

Thirty, 40, 80, and 160 meters are the nighttime DXers' bands. The direction of propagation follows the darkness path across the sky: evening to the east, around midnight to the north and south, and toward the west in the predawn hours. Distances will generally decrease to 1000 miles (1600 km) for skip on these bands. Sporadic-E openings will be most frequently observed around sunrise and sunset toward the end of the month. hr



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FOR SALE: Browning Golden Eagle Mark IV AM/SSB citizen's band receiver. Superb performance—tube-type double conversion, low noise, two tunable bands or crystal controlled. Use on CB, retune for 10 meters, or use as tunable IF for 2 meter, satellite or microwave receiver. Missing top cover, otherwise complete and working, with schematic. $100.00. Peter Ferrand, WB2QLL, 65 Atherton Avenue, Nashua, NH 03060. (603) 889-1067.

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WANTED: ARC-5 and SCR-274 equipment, parts and accessories, any condition. Ken, WB9OZR, 362 Echo Valley, Kinnelon, NJ 07405. (201) 492-9319.

WANTED: Ham equipment and other property. The Radio Club of Junior High School 22 NYC, Inc. is a nonprofit organization, granted 501(C) (3) status by the IRS, incorporated with the goal of using the theme of Ham Radio to further and enhance the education of young people. Your property donation or financial support would be greatly appreciated and acknowledged with a receipt for your tax deductible contribution. In Dayton, meet the crew from 22 and relax at our flea market tables, check in on 144.30 simplex. Please write us at: PO Box 1052, New York, NY 10002. Or call our round the clock hotline: (516) 674-4072. Thank you!

***WANTED:** Drake Linear Amp Model MN4439- 1000W (2000* PEP), 1.8-30 MHz. Call Bruno Molino, VE2FLB, 26 Rue Des Anciens, Gatineau, Quebec J8T 3T2. (819) 561-3669.

RECONDITIONED TEST EQUIPMENT $1.25 for catalog. Walter, 2697 Nickel, San Pablo, CA 94806

COMING EVENTS

Activities — "Places to go . . ."

SPECIAL REQUEST TO ALL AMATEUR RADIO PUBLICITY COORDINATORS: PLEASE INDICATE IN YOUR ANNOUNCEMENTS WHETHER OR NOT YOUR HAMFEST LOCATION, CLASSES, EXAMS, MEETINGS, FLEA MARKETS, ETC, ARE WHEELCHAIR ACCESSIBLE. THIS INFORMATION WOULD BE GREATLY APPRECIATED BY OUR BROTHER/SISTER HAMS WITH LIMITED PHYSICAL ABILITY.

May 5-6: NEBRASKA: Hamboree #11 sponsored by the 3900 Club and the Sooland ARA, Marina Inn, South Sioux City. For reservations write Al Smith, W0PEX, 3529 Douglas Street, Sioux City, IA 51104.

May 7: NEW JERSEY: Annual Indoor Hamfest/Flea Market, sponsored by the Tri-County Radio Association, Passaic Township Community Center, Stirling. 8AM to 2PM. For information/reservations Dick Franklin, PO Box 182, Westfield, NJ 07090. (201) 232-5955.

May 6: NEW YORK: 30th annual Southern Tier Hamfest sponsored by the Southern Tier ARCs (STARC), Tioga County Fairgrounds, Rt 17c, Owego. For information/tickets SASE to STARC, PO Box 7082, Endicott, NY 13760.

May 6: KANSAS: Tailgate Swapfest sponsored by the Flint Hills ARC, Augusta City Park, 20 min east of Wichita. 8AM to 3PM. For information SASE to Zack Wilkerson, K0DVY, Rt 1, Box 90, El Dorado, KS 67042.

May 6: WISCONSIN: The Ozaukee Radio Club will sponsor its 11th annual Swapfest, Circle B Recreation Center, Highway 60, Cedarburg, 8 AM to 1 PM. For information send business SASE to ORC Swapfest, N5415 Crystal Springs Court, Fredonia, WI 53021.

May 6: NEW YORK: The Putnam Emergency Amateur and Radio League will have their PEARLfest at the John F. Kennedy Elementary School, Fogglntown Road, Brewster. 9 AM to 4 PM rain or shine. For registration contact Terri Cullum, N2GWF, 40 Mile Hill Road, Highland, NY 12528 or Jim Morgan, KA2FIQ, 39 Overlook Road, Ossining, NY 10562

May 6-7: MARYLAND: Capital Fest sponsored by the Timex Sinclair Computer Club, Howard Johnson's, Rt 95 & 450, New Carrollton. For information Audrey Curnutt, 10400 Truston Road, Adelphi, MD 20783.

May 5-7: ARIZONA: The Cochise Amateur Radio Association's annual Hamfest, Club training facility, Sierra Vista, tailgating. Handi facilities. For information N7INK (602) 378-3155 after 6 PM or write CARA, PO Box 1855, Sierra Vista, AZ 85636.

May 7: NEW JERSEY: Spring Hamfest sponsored by the Bergen ARA, Bergen Community College, 400 Paramus Rd, Paramus. 8-3. For information Jim Joyce, K2ZO, 286 Ridgewood Blvd, No. Westwood, NJ 07675. (201) 664-6725

May 6-7: SOUTH CAROLINA: 50th annual Greenville Hamfest sponsored by the Blue Ridge Amateur Radio Society, American Legion Fairgrounds, Greenville. Saturday 8-5; Sunday 8-3. For advanced tickets or information SASE to Blue Ridge ARS, POB 6751, Greenville, SC 29606.

May 13: WISCONSIN: Lakeshore Hamfest sponsored by Mancarad Radio Club, Manitowoc County Expo Center, Hwy 42-151 and I-43 on County Hwy R. Starts 8 AM. Contact: Mancarad Radio Club, PO Box 204, Manitowoc, WI 54220.

May 14: OHIO: Medina County Hamfest sponsored by the Medina 2 Meter Group, Medina County Community Center, 735 Lafayette Road, Medina. 8AM to 2PM. For information/tickets SASE to Medina Hamfest Committee, PO Box 452, Medina, OH 44258. (216) 769-3033 or 725-4492. 10AM to 5PM.

May 14: OHIO: 10th annual Hamfest sponsored by the Athens County ARA, City Recreation Center, Athens. 8AM to 3PM. For information Carl J. Denbow, KA8JXG, 63 Morris Avenue, Athens, OH 45701.

May 19-21: OKLAHOMA: Green Country Hamfest, Expo Square Pavillion, 17th and Louisville, Tulsa. Registration Green Country Hamfest, POB 4263, Tulsa, OK 74135. For information (918) 272-3081.

May 19-21: NEW HAMPSHIRE: The 15th annual Eastern VHF/UHF/SHF Conference, sponsored by the Northeast VHF Association, Rivier College, Nashua. Registration chairman David Knight, KA1DT, 15 Oakdale Ave, Nashua, NH 03062.

May 20: MICHIGAN: Swap and Shop sponsored by the Wexaukee ARA, Cadillac Middle School, 500 Chestnut Street, Cadillac. 8:30AM to 2:30PM. Contact John Craddock, KX8Z (616) 797-5491 or Wexaukee ARA, PO Box 163, Cadillac, MI 49601.

May 20: ARKANSAS: Ozark Hamboree sponsored by the Northwest Arkansas ARC, Rodeo Community Center, Springdale. 8AM to 3PM. For information Randall Spear, WA5QGH, (501) 846-3210.

May 20: ILLINOIS: 3rd annual Hamfest and Electronic Flea Market sponsored by the Lewis & Clark Radio Club, Lewis & Clark Community College, Godfrey. 8AM to 3PM. For information/tickets: Lewis & Clark Radio Club, PO Box 553, Godfrey, IL 62035. (618) 466-1909.

May 20-21: WASHINGTON: Hamfest '89 sponsored by the Yakima ARC, Central Wahington State Fairgrounds, Yakima. Contact Dick Umberger, N7HHU (509) 453-8632 days or 453-3580 evenings. Early bird special Yakima ARC, W7AQ, PO Box 9211 Yakima, WA 98909.

May 20: TEXAS: 4th Annual Armed Forces Day Hamfest, sponsored by the Key City ARC, Abilene Civic Center, Pine St, Abilene. 8AM to 5PM. Wheelchair Accessible. For information Bill Jones, N5DOX (915) 698-4606 or KCARC, PO Box 2;722, Abilene, TX 79604.

May 20: MINNESOTA: Swapfest '89 sponsored by the Arrowhead Radio Amateur Club, First United Methodist Church, 230 East Skyline Parkway, Duluth. 10AM to 3PM. For information/registration John Crow, KA0SYN, 1365 Roland Road, Cloquet, MN 55720. (218) 879-5356.

May 20: GEORGIA: 10th annual Lake Hartwell Hamfest sponsored by the Anderson, Hanwell and Toccoa ARCs, Lake Hartwell Group Camp, Hwy 29, 4 miles north of Hartwell. For information George C. Haddock, KB4HCB, Rt 1, Box 52, Martin, GA 30557 or Carl Davis, College Avenue, Hartwell, GA 30603.

May 20: PENNSYLVANIA: Lancaster County Hamfest, sponsored by the Ephrata Area Repeater Society, Ephrata Senior High School, 803 Oak Blvd, Ephrata. Starting 8AM. For information/reservations Tom Youngberg, K3RZF 215) 267-2514 or EARS, 906 Clearview Ave, Ephrata, PA 17522.

May 20: RHODE ISLAND: Spring Flea Market and Auction sponsored by the RI Amateur FM Repeater Service, VFW Post 6342, Main Street, Forestdale (No. Smithfield). Noon to 5 PM. For information contact Rick Fairweather, K1KYI, Box 591, Harrisville, RI 02830. (401) 568-0566 from 7-9 PM.

May 20: COLORADO: 1989 Swapfest sponsored by the Pikes Peak Radio Amateur Association, Rustic Hills Mall, Palmer Park and academy Blvd, Colorado Springs. For information/reservations Al, N0CMW (719) 473-1660 or write PPRAA Swapfest, PO Box 16521, Colorado Springs, CO 80935.

May 21: PENNSYLVANIA: 15th annual Hamfest sponsored by the Warminster ARC, Middletown Grance Fairgrounds, Penns Park Road, Wrightstown. Gates open 8 AM. For information/registration Bill Cusick, W3GJC, Apt 804, Garner House, Hatboro, PA 19040. (215) 441-8048.

May 21: ILLINOIS: Knox County Hamfest, sponsored by the Knox County Radio Club, Knox County Fairgrounds, Knoxville. Starts 8AM. For tickets/information Keith L. Watson, WB9KHL, 119 South Cherry Street #3, Galesburg, IL 61401-4527. (309) 342-3885 evenings.

May 21: WEST VIRGINIA: The 11th annual TSRAC Wheeling Hamfest/Computer Fair, Wheeling Park. 8 AM to 3 PM. To reserve space contact Sandi Williams, WC8P, 9 East High Street, Flushing, OH 43977 (614) 968-3652. For tickets TSRAC, Box 240, RD 1, Adena, OH 43901 (614) 5546-3930.

May 21: ILLINOIS: Hamfest sponsored by the Kankakee Area Radio Society, Will County Fairgrounds, Peotone. 8-3. For information write KARS c/o Frank DalCanton, KA9PWW, RR 1, Box 361, Chebanse, IL 60922. (815) 932-6703 after 4 PM or (815) 937-2452 before 4 PM CST.

May 21: ILLINOIS: Mini-Hamfest sponsored by the Chicago ARC, North Park Village, 5801 N. Pulaski, Chicago. 9AM to 3PM. For information contact CARC, 5631 W. Irving Park Road, Chicago, IL 60634. (312) 545-3622.

May 21: CALIFORNIA: HAMSWAP, sponsored by the North Hills Radio Club, Folsom Community Clubhouse, Folsom. 8 AM to 3 PM. Contact NHRC, PO Box 41635, Sacramento, CA 95841 or call Bob, WA6ULL (916) 983-2776.

May 27: NORTH CAROLINA: 10th annual Durhamfest 1989, sponsored by the Durham FM Association, lower rear deck South Square Mall, Durham, rain or shine. 8AM to 4PM. For information Mick Rankin, W4ZUS, 1001 Wedgewood Lane, Durham, NC 27712.

May 28: MARYLAND: Memorial Day Hamfest sponsored by the Maryland FM Association, Howard County Fairgrounds, Rt 144, West Friendship. 8AM to 3PM. For information/reservations Mike Cresap, 1294 Dorothy Road, Crownsville, MD 21032. (301) 923-3629.

June 3: NEW HAMPSHIRE: The Hosstraders Flea Market is back at the Deerfield Fairgrounds. Admission $5 per person. Wheelchair accessible. Questions or map SASE to WA1IVB, RFD Box 57, West Baldwin, ME 04091.

June 4: MICHIGAN: Swap 'N Shop sponsored by the Chelsea ARC. For information Robert Schantz, 416 Wilkinson Street, Chelsea, MI 48118. (313) 475-1795.

June 4: NEW YORK: Lancaster Hamfest sponsored by the Lancaster ARC, Depew Grove, 271 Columbia at French Rd, Depew. 8AM to 5PM. For information WA2CJJ (716) 681-6410 or KE2FM (716) 681-3512.

June 4: PENNSYLVANIA: 35th annual Hamfest sponsored by the Breeze Shooters, White Swan Amusement Park, Rt 60 (Parkway West) near greater Pittsburgh International Airport. For information John Colbert, K3SDL, 1851 Highland Ave, Irwin, PA 15642. (412) 863-5167.

June 4: NEW YORK: Hall of Science Hamfest, sponsored by the Hall of Science ARC, Hall of Science parking lot, Flushing Meadow Park, 47-01-111 Street, Queens. Starts 9 AM. For information Steve Greenbaum, WB2KDG (718) 898-5599 or Arnie Schitfman, WB2YXB (718) 343-0172.

June 10: MICHIGAN: 15th annual Hamfest sponsored by the Central Michigan Amateur Repeater Association (CMARA), Midland Community Center, Midland. 8AM-1PM. For information SASE to CMARA Hamfest, PO Box 67, Midland, MI 48640
June 10: MAINE: 3rd annual Outdoor Hamfest sponsored by the Pine State ARC, Hammond Street Campground, near 195, Bangor. Dawn to 5 PM. For information Ed Richardson, NO1L, 825-4417; Howie Soule, K1CZ, 848-3397.

June 10: ONTARIO: Central Ontario Amateur Radio Flea Market, Bingeman Park, Kitchener, Ont. Contact Ray Jennings, VE3CZE, 61 Ottawa Crescent, Guelph, Ont. N1E 2A8. (519) 822-8342.

OPERATING EVENTS

"Things to do . . ."

April 30: The Clairemont Repeater Assoc. will operate W6FZZ, SAMS DAY, to honor Samuel F.B. Morse. Samuel F.B. Morse III will be operating from this station. For QSL CLARA, Box 7675, Huntington Beach, CA 92615.

May 13-14: Nevada QSO Party sponsored by the Frontier ARA, Las Vegas. 0000Z May 13 to 0600Z May 14. 6-160m, CW/SSB/FM/RTTY/Packet/SSTV. Mail logs to Jim Frye, NW7O, 4120 Oakhill Ave, Las Vegas, NV 89121.

May 20: The Maryland Mobileers ARC will operate WA3PJQ aboard the Submarine U.S.S. Torsk (SSk-423), 1400Z to 2100Z. For certificate send legal SASE to MMARC, POB 784, Severna Park, MD 21146.

May 20: 40th annual ARMED FORCES DAY. In recognition the ARS W4ODR located Northside aboard Naval Air Station Memphis, Millington, TN, will operate from 1300Z to 2300Z. For addition information W4ODR/Navy—Marine Corps MARS Station NNN0NIF, Bldg N-100, NAS Memphis. (901) 873-5134.

May 20: Special event station KM3I will be on the air to commemorate the 145th anniversary of the telegraph message "What Hath God Wrought?", transmitted on an experimental line from Washington, DC to Baltimore, MO. For a commemorative certificate, Amateurs send QSL card, SWL's send QSO details with large SASE to The Bay Area ARS, PO Box 805, Pasadena, MD 21122-0805.

May 20-21: The St. Charles ARC will operate WB0HSI from 1300Z to 2100Z to commemorate Lewis and Clark Rendezvous Days. For certificate send large SASE to St. Charles ARC, PO Box 1429, St. Charles, MO 63302-1429.

May 21-27: Special event station WA4ZIO will be operating from the Alabama Reunion Train. Sponsored by the Heart of Dixie Railroad Museum, Birmingham ARC and ARRL AL section. 80-10m phone and CW. For certificate send QSL and 9x12 SASE to Birmingham ARC, POB 603, Birmingham, AL 35201.

June 3: The Conemaugh Valley ARC will operate WA3WGN to commemorate the centennial of the flood of 1889 in Johnstown, PA. Lower General phone bands, 20, 40m. Novice phone 10m. For QSL send #10 SASE to Conemaugh Valley ARC, 194 Barron Ave, Johnstown, PA 15906.

June 4: The Wireless Institute of Northern Ohio (WINO) an organization sponsored by the Lake County ARA will operate special event station KO8O from a winery in Madison, Ohio, to commemorate Ohio Wine Month. 1500Z to 1900Z 14235 and 21310 kHz. For QSL send legal SASE to KO8O, WINO Weekend, 10418 Briar Hill, Kirtland, OH 44094.

NORTH COAST ARC 1989 LICENSE EXAMS. 12:30 PM, Saturdays February 11, April 15, June 10, August 12, October 14, December 9. N. Olmsted Community Cabin, S of Lorain on W. Park. Novice thru Extra. Walkins allowed. Talk in 145.29 repeater. For information Dan Sarama, KB8A, 15591 Rademaker Blvd, Brookpark, Ohio 44142. 267-5083 or Pauline Wells, KA8FOE, Rick Wells, K8SCI, 777-9460/779-6999.

AMATEUR RADIO CLASSES: For those people interested in obtaining a Novice (basic level) Ham license or upgrading to Tech/General, the Chelsea Civil Defense, in cooperation with QRA Radio Club, will sponsor Amateur Radio Communications classes evenings at Chelsea High School starting MARCH 7, 1989. For more information write Frank Masucci, K1BPN, 136 Grove Street, Chelsea, MA 02150. Please enclose your telephone number.

THE MIT UHF REPEATER ASSOCIATION and the MIT Radio Society offer monthly HAM EXAMS. All classes Novice to Extra. Wednesday, MAY 24, 7 PM, MIT Room 1-150, 77 Mass Avenue, Cambridge, MA. Reservations requested 2 days in advance. Contact Ron Hoffmann at (617) 484-2098. Exam fee $4.50. Bring a copy of your current license (if any), two forms of picture ID, and a completed form 610 available from the FCC in Quincy, MA (617) 770-4023.

NEW PRODUCTS

Electronic temperature-control soldering station

The Elenco electronic temperature-control soldering station has a circuit which lets you change tip temperature from 300°F (150°C) to 900°F (480°C) without changing the tip or heating element. A temperature sensor located near the tip offers rapid response and little temperature variation. The tip of the unit is isolated from the AC line by a transformer. Low voltage (24 volts) powers the heating element. Completely electronic switching protects voltage and current-sensitive components. This unit has a linear LED array readout which accurately indicates tip temperature. It is priced at $169.

Contact Elenco Electronics, Inc., 150 W. Carpenter Avenue, Wheeling, Illinois 60090 for details.

Circle #309 on Reader Service Card.

Transverter from R N Electronics

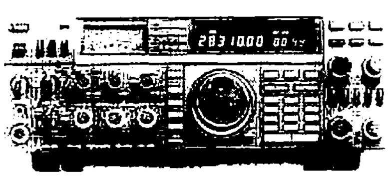
R N Electronics of Essex, England announces the new 2 to 6-meter transverter. It can be used with your existing 2-meter transceiver and has 25 watts PEP output. For more information write R N Electonics, 37 Long Ridings Avenue, Hutton, Brentwood, Essex CM131EE, UK

ICOM's new IC-765 HF transceiver

ICOM announces the new ICOM IC-765 HF transceiver which features

- Direct Digital Synthesizer (DDS)
- Band stacking registers.
- 99 fully tunable memories.
- CW pitch control
- Maximum operating flexibility.
- Built-in AC supply.
- Automatic antenna tuner with built-in CPU and memory.
- 10-Hz readout.

The IC-765 is priced at $3,149, and comes with narrow 500-Hz CW filters. The 250-Hz FL-53A and FL-101 are optional filters.



For details contact ICOM America at 2380 116th Avenue N.E., PO Box C-90029, Bellevue, Washington 98009-9029.

Circle #310 on Reader Service Card.

New manuals from Kantronics

Kantronics, Inc. announces its new manual set. The three manuals included are *Installation Manual*, *Operation Manual*, and *Command Manual*. This set includes instructions for KAM, KPC-2, KPC-2400, and KPC-4.

For more information contact Kantronics, Inc., 1202 E. 23rd Street, Lawrence, Kansas 66046.

Circle #311 on Reader Service Card.

Jensen Tool catalog

A new catalog is offered free by Jensen Tools. Illustrated in full color, the 160-page catalog describes Jensen's full line of over 40 specialty tool kits for field service, plus a new line of products of fiber optics and wire/cable systems. Also included are hand and power tools in English and metric sizes, test equipment, soldering/desoldering stations, static control, lighting/optical aids, carrying cases, shipping containers, and more.

For a copy write Jensen Tools, Inc., 7815 S. 46th Street, Phoenix AZ 85044, or call (602) 968-6231.

Circle #312 on Reader Service Card.

VOICE-ID™ digital voice annunicator

VOICE ID™ can store and reproduce voice messages and/or CW in any logical combination with various delays. It's an add-on device for repeaters and Amateur Radio stations, and of interest to the DX contester.

High-quality, non-robotic voice reproduction is achieved through voice compression algorithms encoded in a non-volatile EPROM. Voice messages are stored in the EPROM, so no re-recording is necessary after a power failure.

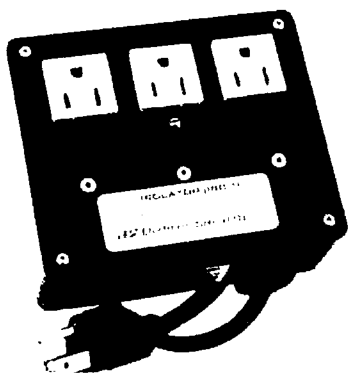
The VOICE-ID™ is field installable, and is suitable for use in remote applications. It may also be battery operated in case of emergency.

For more information contact Time Domain Systems, 5003 Cowell Boulevard, Davis, California 95616.

Circle #313 on Reader Service Card.

Isolator line expanded

Electronic Specialists expands their patented isolator line to include remote power switching, power fail interrupt, and 20-A options. Suppressor performance of all units has been expanded to 39,000 surge amperes for added equipment protection. Isolators, with wideband high attenuation channel filters, are available in commercial, industrial and laboratory grades. Expanded isolator performance and options are available. Prices start at $100.



For details contact Electronic Specialists, Inc., 171 South Main Street, Natick, Massachusetts 01760.

Circle #314 on Reader Service Card.

M-5000 autoranging multimeter

The Elenco M-5000 is a handheld 3-1/2 digit autoranging multimeter VOM functions, Hi-Low ohms, diode check, 10-A AC/DC current ranges, and audible continuity check are standard. Other features include data hold, memory, and manual or autoranging.

The M-5000 comes complete with operator's manual, test leads, and battery. It weighs under 7 ounces and is priced at $69.95.

For details contact Elenco Electronics, Inc. 150 West Carpenter Avenue, Wheeling, Illinois 60090.

Circle #315 on Reader Service Card.

JUNE [illegible]

HAM RADIO

Featured this month...

A Simple DC Amp for your Meter

The Battle of the Beams: Part 1

The NO5H All-band Dipole

June Weekenders

Solid-State Switching the Midland 13-509

and

A Motorized Agitator for your PC Boards

HAM RADIO

JUNE 1989
Volume 22, Number 6

Cover Photo: Kantronics

N2DCH, page 40

K4IPV, page 53

K3OF, page 68

FEATURES

DEPARTMENTS

APRIL WINNERS

Congratulations to Kenneth L. Frank, WB5AKI, our April sweeps winner and Bryan Bergeron, NU1N, author of April's most popular WEEKENDER — "Easy Antenna Access For Urban Apartment Dwellers." Both will receive a copy of *The Radio Handbook* by Bill Orr, W6SAI.

Our WEEKENDER sweepstakes ends with our April winners. Thanks to everyone who sent in cards. Your comments have been invaluable to us!

Terry Northup, KA1STC

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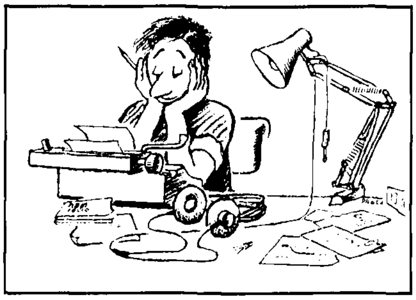
Backscatter



VIEW FROM THE TOP

By the time you get this magazine, the 1989 Dayton Hamvention™ will be a distant memory. However, as I sit here and write today, Dayton is just a week away.

For those of you who've never been to Dayton, it's truly one of the most interesting experiences you'll ever have. Plan to go someday. You'll have the time of your life. The Hamvention is three jam-packed days of the best forums, displays, and opportunities to meet people from around the world. I've run across friends I haven't seen in twenty years, and connected faces to voices from far off DX locations.

If you didn't make Dayton this year, try to set aside time to go next year. It really is one of the most enjoyble events on the ham calendar!

NO-CODE SURVEY RESULTS

An Even Split: 50% for, 50% against

WOW! Did we get a lot of mail.

March's editorial discussed the concept of a no-code license and asked for responses from you, our readers. Quite a few of you took the time to either pen a QSL card with a simple statement or write long thoughtful responses. From simple "Yes!" or "No!" answers, to four-page letters detailing your positions, you sure let us have it with both barrels.

Of the responses we received, there was an even 50-50 split of opinion. The last time no-code was discussed in 1983, the responses to our editorial ran 20 to 1 against a no-code license. What has changed in our hobby over the last few years and what does it mean?

First of all, no-code as a license class won't be the panacea for Amateur Radio's problems. It is, however, a step recognizing that not everyone who would like to be ham wants to learn the Morse code. As currently envisioned, a no-code licensee's privileges would be for bands above 50 MHz only. Many of you are under the impression that there would be a below 30 MHz no-code license. That is simply not the case.

A number of you feel strongly that CW acts as a "lid filter," or a way to weed out undesirable potential new hams. That's what they told me about pledging a fraternity in college — going through it would make a better brother out of me. I didn't buy it then and I don't today. Hazing has all but been eliminated from our society. Most of us recognize that it's better to stimulate a person with positive motivation than with "trials" and tests, or hurdles to overcome.

Several of you commented that there is already (for all intents and purposes) a no-code license — CB. However, CBers are not hams and are missing all of the benefits that we, as hams, share. Besides, CB radio was never intended to be an outlet for casual communications.

A significant number of letters commented on the fact that CW is fun. While I agree wholeheartedly, I know many good hams who hate CW and, after passing the General class exam, never want to see a key again.

On the pro no-code side, the general trend supported the realization that not everyone who wants to be a ham wants to learn the code. In this light, most felt that a VHF or UHF only no-code license would be a good idea. No one suggested that a no-code license be a freebie or giveaway ticket. Some suggested that the no-code exam be made harder than the current Extra exam, while others felt that a license on par with either the current Novice or Technician class license was in order.

So, what's next? There have been several very interesting developments. On March 16, 1989, the Space Coast Amateur Technical Group in Melbourne, Florida made a formal filing with the FCC for a no-code license. At almost the same time, the ARRL No-code Study Committee made a proposal to the Executive Committee for a new license class without a code requirement. The ARRL Board will discuss this step further at their July meeting. If it is adopted as policy, the Board may direct League counsel to draft and submit a proposal for a no-code license to the FCC by this fall.

The bottom line is that a no-code license won't result in an explosion in new Amateur Radio licenses. It will, however, provide another path for bringing people into the hobby. It then becomes incumbent upon us to get others interested in Amateur Radio.

One rap made by several writers was that no-code is nothing but an attempt by the Amateur Radio industry to increase the number of licensees in order to enhance their profit margins. Nothing could be further from the truth. The accusers fail to recognize that many of us in the business are long-time hams ourselves. While we may be in business to make a profit, that is not the sole force that drives us. Many of us are driven by our love for the hobby and our desire to ensure that there is a future for Amateur Radio. It's often very difficult to separate the emotional from the rational when it comes to Amateur Radio.

Time, the ARRL, the FCC, and the rest of us will determine whether or not there will be a no-code license. If you're currently against no-code, please ask yourself if you're being fair to those who want to be hams without learning the code. There are people out there with much to offer for whom the code would not be a vital communications skill. Who knows what benefits they could bring to our hobby if we were to encourage them?

de N1ACH

Comments

Self portrait

Dear HR

RE: the February issue, WHAT A GREAT COVER!!!!

I am a broadcast engineer, have been a ham for 36 years, and do a great deal of design and repair work. I am completely at home around electronics.

I recently bought a state-of-the-art rig, and my expression upon spreading out the circuit diagram was almost EXACTLY the same as the person depicted on the cover. With *all* my years of experience, it took me about an hour to figure out where the signal came in, and went out. I still haven't figured out much in between.

Keep up the good work on a good magazine.

Walter Boller, W9OBG/7,
Olalla, Washington 98359

Voice versus packet racket

Dear HR

An electronic plague has decended upon Amateur Radio. Long-standing nets and discussion groups have been pushed out of existence by the agonizing, screeching tide of packet racket. Large numbers of those who might well be the majority in our hobby now find it impossible to monitor their favorite frequency because a packet station has plopped down on it or near it. Who can stand that piercing sound that has been likened to that of fingernails on a blackboard?

A typical example is found when monitoring 144.9 MHz. This frequency has been used for fast-scan TV liason for over thirty years. It is important for signal reports, homing-in antennas, and guiding transmitter/modulator adjustments. An S-9 packet signal on 144.905, while not even moving the meter on adjacent channels, breaks through and can be heard 10 kHz up and down. The worst part is that the RF burst lasts longer and blocks all but the strongest voice signals on 144.9.

When I first read about packet in *QST*, it was described as the ultimate in space-age technology. Economy in use of the spectrum was the keynote in this discussion, due to its inherent speed and accuracy. This allows a large number of operators to be serviced by one system. What it really amounted to, in may cases, was a new justification for having spent hundreds of dollars on a computer that started gathering dust after the novelty had worn off. Although most Hams can talk well and many can even chew gum at the same time, this great store of wit and wisdom had to be digitized, dehumanized, and stored in libraries called bulletin boards. I guess it goes along with the inability to listen and write: a product of our "space-age" school systems.

In any case, the basic pleasures of Amateur Radio, hearing a voice from afar, sensing its emotions, its unique sounds, are being bittered. It is bad enough to lose frequencies to commercial interests, but it is much worse to have them rendered unlistenable by your own group. This could be the final assault in which Amateur Radio, like all the great empires, falls from within.

John Shelley, WA1IAO,
N. Granby, Connecticut 06060

Another viewpoint

Dear HR

Today I received my February 1989 issue of HAM RADIO, and I just completed reading AA6FW's comments concerning youth and ham radio. I am especially interested because I am the author of the August 1988 letter that mentioned "gimmees and wanna be's..." you referred to.

I agree with several of your view points:

1. Yes, radio seems no longer to be a mysterious mechanism to most people.
2. Yes, perhaps many ham radio operators are senior citizens that clump to 80 meters and BS about nothing.
3. Yes, perhaps many hams do not appreciate growth.
4. Yes, incentive must come from more than the ARRL.
5. Yes, perhaps, a no-code license will be incentive for newcomers to ham radio.

However, I challenge many of the arguments used to support these viewpoints. My letter last summer expressed my concerns about the few numbers of younger people being licensed. I appreciate that my perspective will always be one-sided. Nevertheless, it's been my experience that incentive has to come from within.

This is apparent in the workplace and at home. I am an engineer with many years in the IC construction business. The latest craze in productivity is "taking ownership." That's great from the manager's position. My experience, with peers, subordinates, and business contacts, has been that this ownership *has* to already be in place *and active; it cannot be forced. I can make* someone own a project but I cannot (and do not) expect the same results I would get if that ownership were sincere.

The same is true with ham radio. This hobby has and always will provide technical challenges and satisfaction for those willing to move forward. The old saying, "You can take a horse to water but you can't make him drink," is appropriate. I worked with high school kids a few years in a program (Explorer's Group) involving them with the wonders of engineering and science. Either they are interested or they are not.

I chuckled as I read the comments about not being able to find someone to talk to. With half a million hams in this country? My face flushed as I read about (you) not having much to say to such a person (as me) on the air because of my "wanna be's" letter Oh well.

The expectations placed on kids today (from my very middle-class and former welfare-recipient position) are overpowering and sometimes unrealistic. Couple this with today's amazing feats that are taken for granted, along with life being taken for granted, and suddenly ham radio is uninteresting. However, incentive and support are the key ingredients to get more youth into ham radio. How about joining a club and getting involved with youth to show them examples of ham radio and its challenges.

Lawrence Caracciolo, N3CCW,
Federal Way, Washington

Thoughtful response

Dear HR

I would like to respond, in part, to the letter by Harry Helms, AA6FW, which was in the February issue.

To begin with, I can see that there has been a stagnation in membership in our fraternity. I agree that it is a good idea to take every opportunity to involve new people in Amateur Radio.

Mr. Helms complains that Amateur Radio has been "curmudgeonized." Then he says that he has a hard time finding anyone "stateside" with whom he can have a ragchew. May I submit that Mr. Helms has become somewhat of an elitist.

Why does he believe that those who defend the need for a code requirement should have an Extra class license? I freely defend the code requirement and recognize that it is a discipline, even though I dislike using CW intensely. Those who wish to upgrade should do that which is necessary. Others, such as myself, will occasionally use CW on the low bands, or not, as they desire.

I find offensive the implication that because I started in Amateur Radio with a conditional license, that license is tainted. My licenses cover a period of over twenty-five years. During that time, I have assisted in a number of emergencies and tried to be helpful to other Amateurs.

I have never considered it my place to judge them.

Jerome W. Silverstein, K3FKI,
Verona Pennsylvania 15147

Reading the "small" print

Dear HR

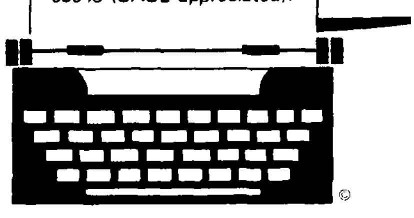
Please accept my compliments for your work with *Ham Radio*. I have gotten the magazine for many years and keep them all as a very valuable source of reference in most ham matters. There have through the years been some outstanding articles, like the series on Yagi Antennas by W2PV and now lately Ron Todd's "Pathfinder" (which gives me a lot of pleasure to operate and gave me a lot of fun to implement). "Pathfinder: Part 1" was easy as you printed the program with letters large enough for my 67 year old vision to see without a magnifying glass. The second part was tougher due to the "magnifying glass" print. But don't you worry also the sun has its spots (fortunately).

So thanks again for a fine job.

Bo Stjernberg, SM6ASD,
Goteborg, Sweden

Invitation to Authors

ham radio welcomes manuscripts from readers. If you have an idea for an article you'd like to have considered for publication, send for a free copy of the *ham radio* Author's Guide. Address your request to *ham radio*, Greenville, New Hampshire 03048 (SASE appreciated).



A SIMPLE DC AMPLIFIER
FOR YOUR METER

By Yardley Beers, WØJF, 740 Willowbrook Road, Boulder, Colorado 80302

By connecting a simple amplifier to one of those old meters you probably have in your shack, you can enjoy a device that gives a full scale deflection for a couple of millivolts or a few microamperes. You can assemble such an amplifier using a common op amp circuit and easily obtained components. If you are unfamiliar with op amps, building this amplifier can be educational as well.

A meter with this kind of amplifier has many uses in the shack. If you connect a diode between its terminals and use a foot or two of loose wire as an antenna, it becomes a sensitive field strength meter. You can improve the sensitivity by using an RF choke and bypass capacitor as shown in **Figure 1**, but these components aren't often required.

You might also find this meter helpful for adjusting QRP equipment. You need some deflection on your meter to know if your adjustments are making things better or worse. Adding this amplifier to your meter makes it possible to study leaks in shielding. When connected to a tuned circuit, it can be used to identify harmonics. The modified meter can also be used as a sensitive bridge balance detector.

This meter and amplifier arrangement can demonstrate a number of effects not usually part of Amateur experience. If you connect a diode in a transparent case to the meter, you'll often find that the diode is sensitive to light, while the meter deflection is of opposite polarity to that produced by RF. (The moral here is that circuit boards with such diodes should be shielded from light.) The meter can also be used to demonstrate thermoelectric effects using ordinary metals, even though there's a bad impedance mismatch between a thermocouple and the amplifier input. Take a piece of copper wire and a piece of aluminum wire and twist one end of each together. Connect the other ends to the amplifier input, with the copper wire attached to the positive terminal. The meter will deflect when you heat the junction gently with a soldering iron. If you use special thermocouple wire, it's possible to get a deflection simply by pinching the junction between your fingers.

I have found these meters useful in working with my homemade QRP microwave demonstration setup.[1] The 1N34s and some surplus diodes have considerable response at 2.4 GHz, but not as much as microwave hot carrier diodes. The 1N914s aren't sensitive to this radiation, or to light. I don't have a microwave oven, but I believe a proper diode connected to one of these meters could detect leaks in the shielding.

The focus of this article is on the use of op amps as DC amplifiers. These amplifiers can also be used to amplify AC signals at millivolt levels. At higher levels the amplifiers overload, and the output approaches zero. They are especially effective when the signal source has a high impedance and the load has a low impedance. I connected a pair of 8-ohm headphones through one of them to the output of a broadcast band crystal receiver. With the amplifier turned off, I could hear nothing. With it on, I heard several stations with excellent volume.

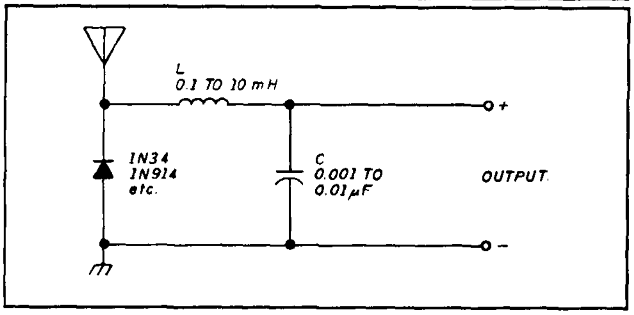
Op amp fundamentals

An op amp is a high-gain amplifier with two input terminals. (See **Figure 2**.) Voltage applied to the noninverting input terminal gives an output voltage of the same polarity. Voltage applied to inverting input terminal gives an output voltage of the opposite polarity. Internal negative feedback tries to make the voltage between the input terminals zero. The output voltage is proportional to the difference between the voltages that would occur between these terminals in the absence of this feedback.

In many applications, one of the input terminals is tied to ground and the input voltage is applied to the other input terminal. In the application used here the input signal is connected bewteen the noninverting input and ground. External negative feedback is established by connecting a resistor (Rf) between the output and inverting input terminals and a resistor (Rs) from the inverting input to ground. If the open loop gain of the amplifier is very high the voltage gain is:

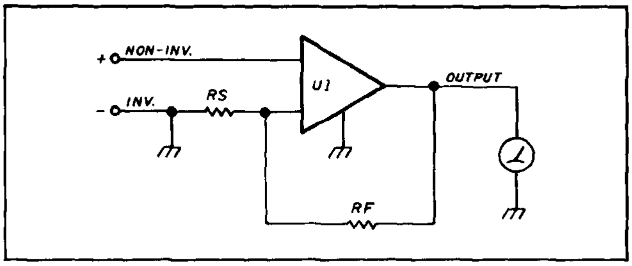
$$G = 1 + Rf/Rs \qquad \textbf{(1)}$$

FIGURE 1



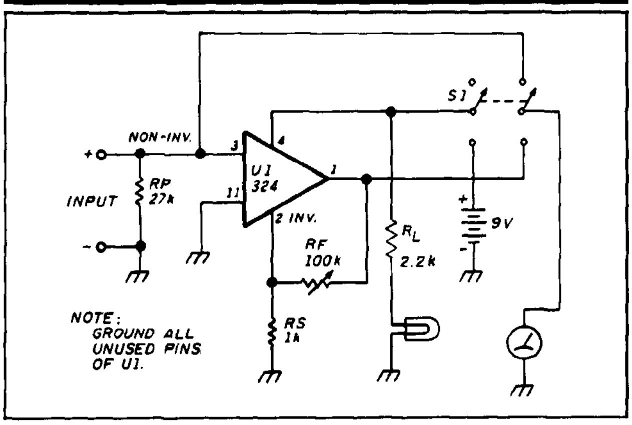
Diode detector circuit.

FIGURE 2



Basic circuit for operational amplifier.

FIGURE 3



Circuit for LM324 Operational ampifier.

If you use very large values of Rf, the amplifier becomes unstable. The maximum usable value depends a little on the input resistance. With Rs = 1 k, I find the maximum practical value for Rf in both circuits is about 100 k. This means the maximum theoretical value of G is about 100. The measured experimental values are close to this value.

In principle, the output voltage is zero when the voltage between the input terminals is zero — regardless of the resistance between these terminals. The LM324 amplifier in **Figure 3** is designed to produce zero output under these conditions; the LM741 circuit in **Figure 4** contains an adjustment for controlling this "zero offset." In either case, the output voltage doesn't remain zero for large input resistances and the amplifier may become unstable. Consequently, I've placed a resistor (Rp) in parallel with the input to prevent the meter from going off scale when the input terminals are open circuited.

The input resistance looking into the op amp is very high — on the order of megohms. This means the resistance looking into the terminals of the circuits shown in **Figures 3** and **4** is essentially that of Rp. The output resistance is very low (less than 1 ohm).

Moving coil meter fundamentals

The op amp's performance depends on the properties of the meter it's used with. I based my assumptions on a meter that has a full scale deflection for 1-mA input and a resistance of 200 ohms. This meter can measure current or voltage, depending on the values of the resistances present in the circuit to which it's connected. In electronic circuits these values are in thousands of ohms, and it's appropriate to connect the meter in series with some portion of the circuit and use it to measure current. In very low resistance circuits (like those composed of thermocouples), you may think of this meter as one for measuring voltage and requiring 200 mV for full scale deflection.

Power is the fundamental quantity determining the deflection. Replacing the moving coil with another coil having the same external dimensions but more turns of inner wire decreases the current required for full scale deflection. At the same time, it needs less voltage because the resistance is higher. Using the simplifying assumption that in both cases the space occupied by the insulation on the wire is negligible, you can see that the change in current compensates for the change in voltage while the power is exactly the same — 200 μW. Therefore, obtaining maximum meter deflection involves an impedance-matching problem.

Response time is one property of the meter that I've overlooked. Replacing the coil with one that has larger external dimensions increases the sensitivity. But because the coil contains more mass, the needle moves more slowly. An alternative is to replace the original spring with one that isn't as stiff. This increases both sensitivity and response; but, the meter also becomes more sensitive to vibration.

Selecting a meter to use with the op amp

Meter selection isn't terribly critical. A voltage gain of about 100 and a very low output resistance are central properties of the op amp. The meter can thus be considered a millivoltmeter. You'll get the greatest sensitivity from a meter that requires the fewest millivolts for full scale deflection. However, the ICs have a rated maximum output current on the order of 20 mA, and it appears that a meter with a full scale deflection for a current of this size would be optimum.

I checked the millivolt calibrations of a number of different meters with full scale current ratings between 0.2 and 25 mA. Contrary to what *I said* before, there was very little difference. All the meters gave a full scale deflection at about 200 mV, within a factor of 2 or so. Apparently my previous assumptions don't apply. Instead, it seems the manufacturers have adjusted the parameters of their meters to make this voltage difference a design objective. However, meters with lower current ratings can save battery drain.

You may wish to build two tip jacks into the unit and use a meter from your shack (a volt ohmmeter switched to a milliam-

pere scale, for instance). If you want a very compact instrument, you can use a surplus tuning meter.

Circuit for the LM324 op amp

The chip containing the LM324 op amp has four units. The circuit in **Figure 3** uses only one of them. This circuit is identical to **Figure 2** except for the inclusion of the input resistor Rp, the battery, and an on/off switch.

The LM324 offers you the simplicity of using a battery with one polarity and wide voltage flexibility. As I said before, it is supposed to be balanced so that it has zero output for zero voltage input — regardless of the external resistance connected to it. In practice this balance isn't perfect, and I've introduced the resistance Rp = 27 k to keep the output voltage within reason. You might want to try other values. The input voltage for full scale output is about 2 mV. The corresponding current is this voltage divided by the value of Rp, or about 0.07 μA. With the 1-mA, 200-ohm output meter this corresponds to a current gain of 14,000. The input power is 0.140 $\mu\mu$W, while output power is 0.2 mW. The power gain is 1,400,000 or about 61 dB.

This circuit is simpler than that of the LM741. You pay for that simplicity by giving up a good method of controlling the zero offset. The power and current gains are limited by the relatively low value of Rp. One way to control the zero offset would be to connect a variable bucking voltage in series with the input, dispensing with Rp. If this were calibrated, the meter could be used as a null indicator and the unknown voltage would be equal to the bucking voltage.

Circuit for the LM741 op amp

The LM741 requires power supply voltages of both polarities with respect to ground. I use a single 9-volt battery with a voltage divider (R1 and R2 in **Figure 4**). By making R1 variable, I have incorporated a method for controlling the zero offset. (Another way is to connect a potentiometer to pins 1 and 5, which are not used in this circuit.)

The ability to control the zero offset makes it practical to use a higher resistance for Rp = 1 meg. With the same voltage gain value of 100, the current for full scale output is now 0.002 μA, and the current gain is 10,000. The power input is 4 $\mu\mu$W, and the power gain is 50,000,000 or 77 dB.

Construction methods

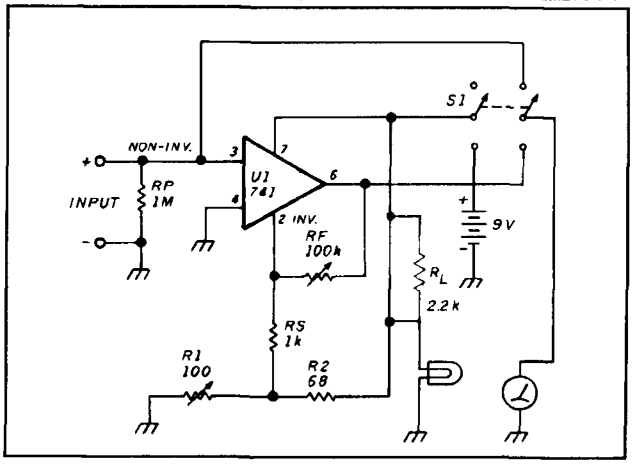
This project allows for great flexibility in construction methods. I've built two LM324 amplifiers and one LM741. One is housed in a meter case with a 3-inch meter. A second is in a 1-1/2″ × 2″ × 3-1/8″ mini box with pin jacks for the meter. The third is mounted in a sardine can with tip jacks for the meter. (There's room to mount a surplus tuning meter.) All three contain 9-volt batteries.

The IC is hard wired into the circuit and supported from other components by its leads. You may want to mount a terminal strip in the box along with one or two insulated terminals in the LM324 circuit. Using the LM741 requires a terminal strip with four or five insulated terminals because of the voltage divider.

Calibration

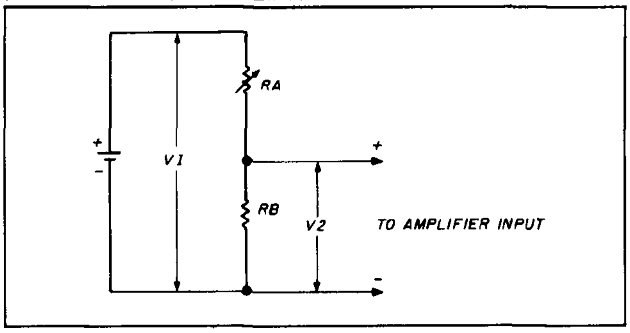
Accurate calibration isn't required in many applications. However, you can obtain a calibration by using the circuit

FIGURE 4



Circuit for LM741 operational amplifier.

FIGURE 5



Calibration circuit.

shown in **Figure 5**. In this circuit resistors Ra and Rb are in series across known voltage V1 (conveniently supplied by a flashlight cell), and voltage V2 is across Rb and applied to the input of the amplifier. Rb should be small (I use 1 ohm). Ra is adjusted to give a full scale reading. Find the value of Ra with an ohmmeter. The voltage at the input is: Rb × Vl/(Ra + Rb). The same scheme can be used with the amplifier turned off for determining the millivolt calibration of the meter. The voltage gain is given by the ratio of the two values of Ra, if the value of Rb is small by comparison.

You can obtain the current calibration from the voltage calibration and the known value of Rp. You can also find it directly by using the voltage divider circuit. To do so, connect a known resistance Rm — on the order of megohms — between the voltage divider and the input of the amplifier; then adjust Ra for full scale deflection. Assuming that the voltage across the terminals of the IC is negligible when compared with V2, the current for full scale deflection is V2/Rm.

Refinements

I have given the details for a simple construction project which creates a compact instrument. There are a number of refinements you can add to make this device more useful.

- You can build the detector shown in **Figure 1** into the box that holds the op amp. It can be disconnected by an SPST switch in series with the diode. The presence of the choke

and bypass capacitor aren't likely to affect the amplifier's use in other applications.

- Figures 3 and 4 suggest that the feedback resistor Rf is a continuously *variable* resistor. There are times when you may want to reduce the gain, but have reproducible settings. I suggest using a tap switch with fixed resistors valued at 1 k, 3.3 k, 10 k, 33 k, and 100 k corresponding to approximately 10-dB changes in gain. If the switch has some extra positions, you might use one of them for a 220 or 330-k resistor.
- There's a gap in sensitivities with high-resistance input sources. With the amplifier off, the input is too small to give a detectable reading at some input levels. With the amplifier on, and with the lowest gain setting, the meter is off scale. For convenience, switch in some resistors in shunt with the amplifier input to bridge this gap. You'll have to experiment to find the specific values needed for a particular circumstance.
- You might want to add a reversing switch, especially if you plan to use the amplifier with inputs of both polarities. Add the switch at the input for the LM324 amplifier, and insulate both input terminals from ground. When the internal zeroing action is working correctly, the circuit won't respond to signals of the incorrect polarity. The meter refuses to deflect at all, rather than deflect backwards. If you're using the LM741 amplifier, place the reversing switch at the output, where it can be useful in adjusting the balance.
- As I suggested earlier, you might build a calibrated source of bucking voltage into the input of an LM324 amplifier.

Conclusion

Beginners should find this article a helpful introduction to op amps. Op amps have wide applications. While they are most often used as some form of DC amplifier, they may also be used as AC amplifiers. Such amplifiers should have blocking capacitors. It's more feasible to cascade AC amplifiers because the zero offset of one stage is not amplified by the next. If you use feedback networks with capacitors, the op amp becomes a very effective filter.

These are topics discussed in many current magazine articles as well as the references given below[2-6]. For beginners, I recommend **Reference 3**. For an advanced treatment read **Reference 5**. It contains internal circuit diagrams of the LM324 and LM741 amplifiers along with data on their ratings. For practical circuits using operation amplifiers in diverse applications, I suggest **Reference 6**. For a discussion of the zero offset problem and some of the improved op amp chips now available, see **Reference 7**. **Reference 8** and **9** are useful survey articles on op amps. **hr**

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6 *Forrest M. Mims III, Engineer's Notebook II*, Radio Shack, 1980
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8 Joe Carr, K4IPV, "Practically Speaking: An Overview of Operational Amplifiers Part 1," *Ham Radio*, November 1988, page 100
9 Joe Carr, K4IPV, "Practically Speaking: An Overview of Operational Amplifiers Part 2," *Ham Radio*, December 1988, page 83.

SOLID-STATE SWITCHING THE MIDLAND 13-509

By Nick Ciarallo, VE2HOT, 85 Celtic Drive, Beaconsfield, Quebec H9W-3M6

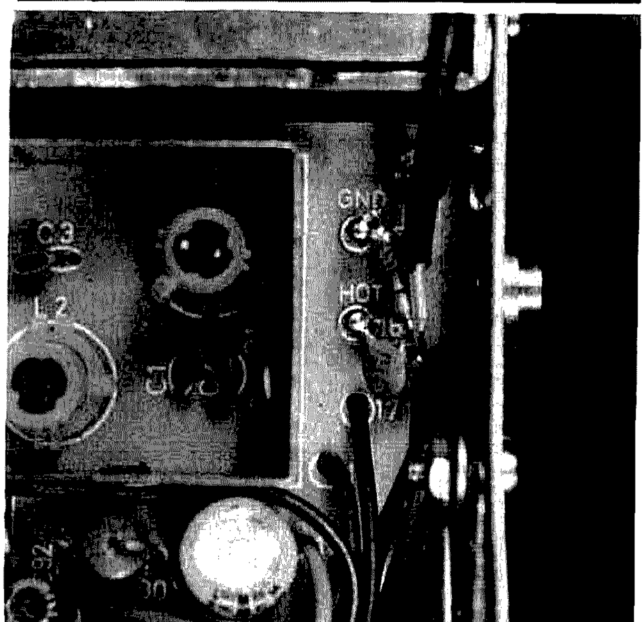
If you have a Midland 13-509, you might have the same problem I had. About two years ago, the TX/RX relay was on its way out and was driving me crazy! The radio transmitted intermittently, so I suspected the relay. It looked hopeless and I decided to trash it. I've seen articles on solid-state switching for other radios, but nothing for the famous 13-509. So, as they say, I had to "roll my own." Because I would be removing the relay, I had to make sure the circuit would do what the relay did. That is:

- Supply +12 volts to the transmitter and the PIN diode switch when keyed.
- Supply the receiver with +12 volts when unkeyed.
- Handle the RF switching.

How it works

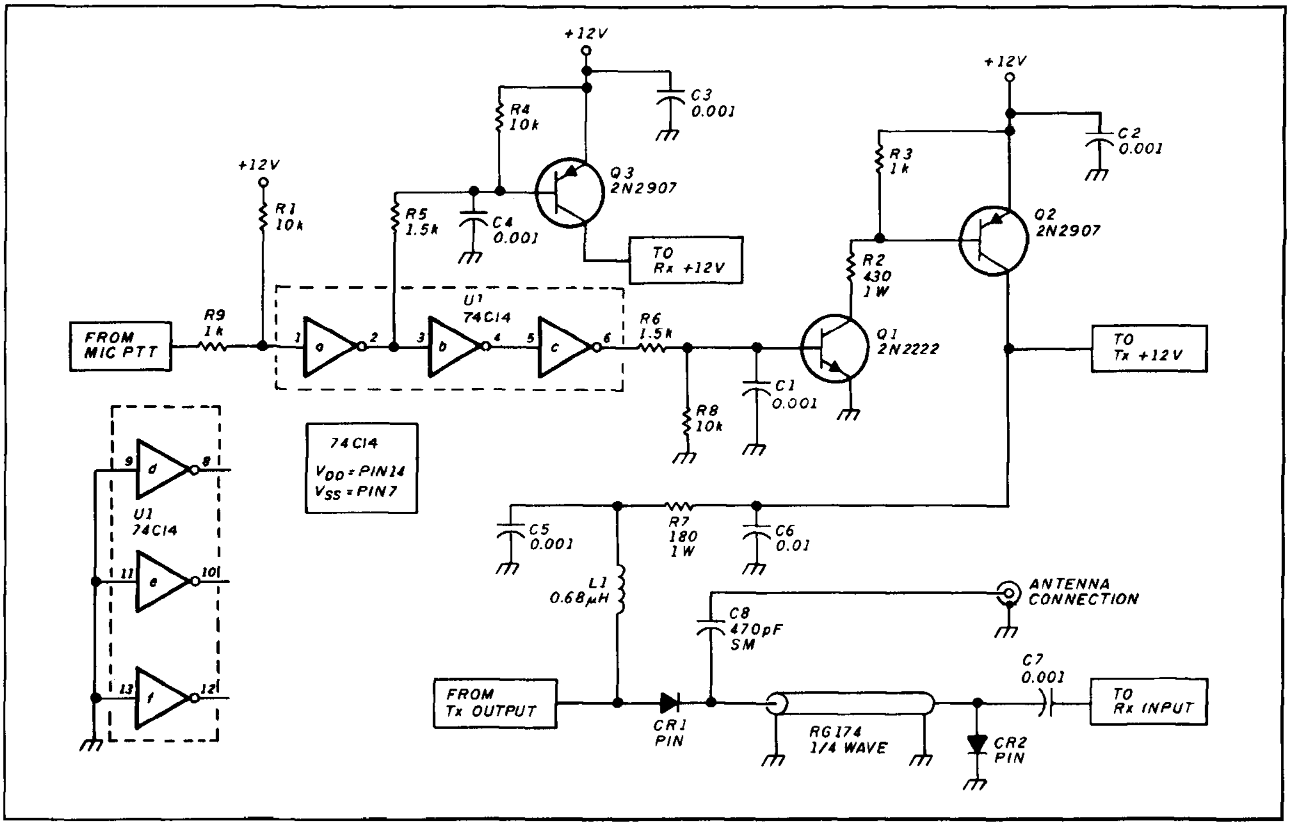
When the radio is keyed, the RF switch has to show the transmitter a short circuit (or something close to it) to the antenna. At the same time, the switch must isolate the receiver's sensitive front-end components from the transmitter's high-power signal. When the radio is keyed, both PIN diodes are turned on (see **Figure 1**). The first PIN (CR1) provides a low-impedance path for the transmitter to load into the antenna; the second PIN (CR2) is essentially a short circuit at the receiver input. The coax between the receiver and antenna acts like an impedance transformer because it's a quarter wavelength long at 223 MHz. This makes the short circuit caused by PIN diode CR2 at the receiver input look like a high impedance at the antenna. When you unkey the radio and put the switch in receive mode, both PIN diodes are removed from the circuit because they no longer have any bias current. The antenna now sees a high-impedance path to the transmitter and a short circuit to the receiver. Consequently, none of the received signal is

PHOTO A



Receiver PIN diode Installation (CR2 in *Figure 1*). The PIN diode is located next to the word HOT. Note there is no excess length where the RG-174 makes its connection to the diode.

FIGURE 1



The 13-509 PIN diode switch schematic. Note the unused inputs of the 74C14 are connected to ground.

absorbed by the transmitter's output circuitry and there's no loss of receiver sensitivity. If you want to know more about PIN diodes and PIN switches, OA4KO/YV5 has written an excellent article on the subject.[1]

The design

First, I removed the relay. Then I measured the current requirements for the transmitter and receiver. The switched 12-volt line that feeds the transmitter supplies everything except the driver and final. The current drawn by these stages is about 200 mA. The receiver draws 140 mA at full volume, unsquelched. The PIN diode switch requires 60 mA (a little less than the relay). Armed with this information, I was ready to design the DC switching circuit. The most convenient way to do the switching was to start with a hex inverter to provide the appropriate levels, and then buffer the outputs to supply the required current. I selected a 74C14. Because the current demands for the radio aren't very large, you can use small transistors. I used 2N2907s and they worked just fine. Empirically select the resistor that determines the bias current for the PIN diodes. The resistor you use depends on which diodes you choose. Almost any PIN diode will work; just make sure it can handle the power. Don't shy away from ones that look like 1N914s; they can probably handle a hundred watts. Check the specs!

The transformer

The coaxial transformer for 223 MHz is 8.75" long and

PARTS LIST

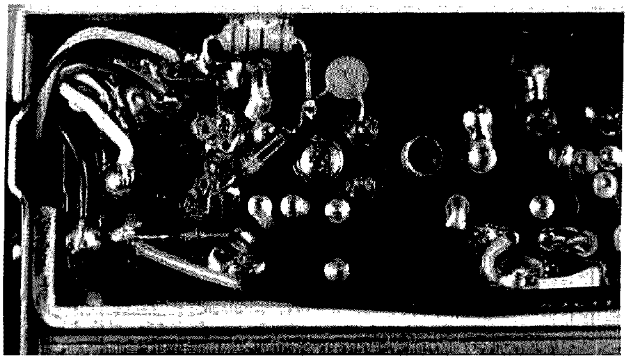
CAPACITORS		**DIODES**	
2	0.01 µF	2	PIN diodes (see article description)
5	0.001 µF		
1	470 pF/SM		
RESISTORS		**SEMICONDUCTORS**	
1	180/1 watt	1	2N2222
1	430/1 watt	2	2N2907
2	1 k	1	74C14
2	1.5 k		
3	10 k		
INDUCTORS		**MISCELLANEOUS**	
1	0.68 µH		10" piece of RG-174 50-ohm coax perfboard

is made from RG-174 mini coax. Make sure the 50-ohm section is the proper length. If you cut a piece of coax that is 10" long and strip off and separate 1/2" from each end, the actual 50-ohm section will be 9 inches. The formula for determining the coaxial cable length is as follows:

$1946/F_0 = L$

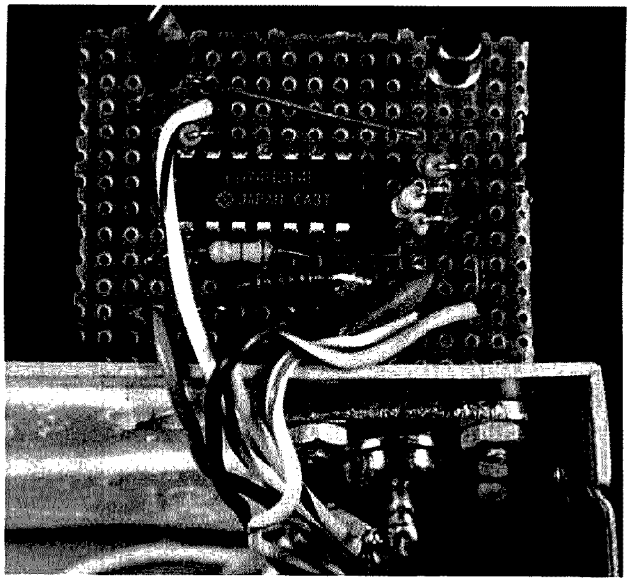
where F_0 is the frequency in MHz, and
where L is the length in inches
for 66-percent velocity factor coax
example: $1946/223.0 = 8.73''$;
round off to 8.75"

PHOTO B



Transmitter PIN diode installation. There are "stripline" inductors for SWR protection circuit. Again, note there is no excess lead length where the RG-174 connects to the PIN diode.

PHOTO C



Completed circuit before installation. A 74HC14 was used in the original design; the 74C14 has been substituted due to greater availability.

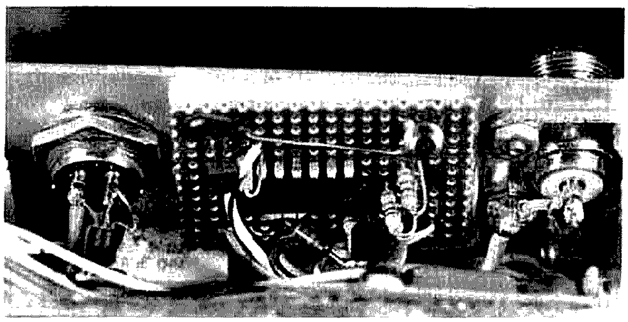
Installation

I mounted the PIN diode and coupling cap for the receiver across the antenna input terminals on the receiver strip (see Photo A) and ran the quarter-wave coaxial transformer over to the antenna connection, where the relay used to be. I installed the PIN diode for the transmitter on the foil side of the board near the relay location, after the "stripline inductor" which couples RF to a second stripline inductor located next to it (see Photo B). These inductors are actually parallel traces on the pc board, used to couple RF to the diode that detects reflected power for the VSWR protection circuit. My last addition was a capacitor right at the antenna connector. I used a 470-pF silver mica unit. You must install this cap to prevent the +12 volt (TX) switched line from supplying the antenna with DC. In my tests, this capacitor didn't affect the performance of the radio in any way.

I built the logic circuit on a small piece of perfboard. The relay pads provide all the connections necessary for the solid-state switch. Make sure you tie all unused inputs of the 74C14 to ground and bypass the chip by placing a 0.01-μF capacitor across its supply pins. Keep all RF connections as short as possible.

Photo C shows the solid-state switch just before installation. I used double-sided tape to mount the completed circuit in the compartment at the back of the radio where the relay used to be. Photo D shows the circuit mounted with double-sided tape.

PHOTO D



The PIN diode switch Installed. The double-sided tape holds the complete PIN diode switch assembly securely.

Results

Your radio will switch quickly after you make these modifications. I measured 20 ms to full power, which is an improvement on an already fast-switching radio. Receiver sensitivity improved and the radio is now quieter since I've removed what had become (in my radio, anyway) a very lossy relay. The same holds true for the transmitter.

The power output increased 4 watts. This 4-watt difference equates to the removal of about 1.6 dB of insertion loss! Since the RX/TX turnaround time is faster, you can use the radio for high-speed packet linking without worrying that the relay will die in mid-January at your remote repeater site. After over two years of daily service with this modification installed, my radio hasn't given me any problems.

Final note

I'd like to hear from anyone with suggestions and/or modifications for this circuit. If you have questions about the circuit and its installation, send me an SASE and I'll try to answer you as fast as possible. I'd like to thank Jean-Guy Deschênes, VE2BEY; Henry Szczawinski, VE2BJR; Ben Soo; and Dino Moriello, VE2FSA, for their help in putting this article together. If you have a question that you feel can be answered on packet, I can be reached at NA2B.

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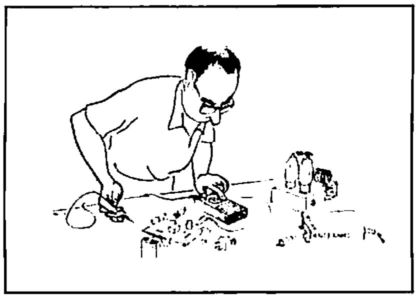
Ham Radio Techniques



Bill Orr, W6SAI

COAX REVISITED

We were jammed in the tail of the A-20 (Boston) attack bomber, electrical cables and steel control wires all around us. It was pitch black except for the beam of my flashlight. The noise was deafening. Herbie, W6KJT, leaned against me and shouted in my ear, "Feel the cable!" I did as he told me and found that the coax cable was very warm to the touch. I knew the cable was running hot because of the RF in it. I had just turned on the aircraft transmitter a few moments before and locked the key. Then we had crawled to the back of the fuselage to determine the condition of the coax feeding the antenna.

"That's only 100 watts in the cable," he yelled. "Come along with me!" We squirmed forward, dropped into the bomb bay of the fuselage, and slid to the cement floor of the factory. I turned off the transmitter on my way out of the aircraft.

The A-20 production line stretched, plane after plane, until it disappeared at the back of the Douglas Aircraft assembly plant. At the far end of the line, the skeleton frames of the A-20s were attacked by gangs of riveters whose tools made an ear-splitting din — like that of a thousand machine guns. As the planes progressed along the line, their wings, engines, landing gear, and other major parts were added. By the time an aircraft reached the point on the line where we were standing (next to the huge hangar doors) it was complete, loaded with radio and navigation equipment, and almost ready for flight testing.

It was mid-summer 1941 and the building was hot. Herbie dusted himself off and led me to the radio room at the side of the building. "Starting right now, on plane number 386, we stop using this old copolene-insulated coax line and start using some new coax called WC-549. It has a brand-new polyethylene inner dielectric and is rated for use at 400-watts power up to 200 megacycles!"

Two hundred megacycles! I looked at the new coax, glistening in its black jacket. Just the thing for my post-war ham rig! W6KJT grinned as he read my thoughts. He pointed to a large box full of interesting devices. "New style coax plugs and receptacles! The military nomenclature is PL-259 for the plug and SO-239 for the socket. There's also a splice adapter. When all of this stuff gets on the market after the war, ham radio will never be the same again!"

I agreed. But how much would this new, efficient coax line cost? Maybe hams wouldn't be able to afford it!

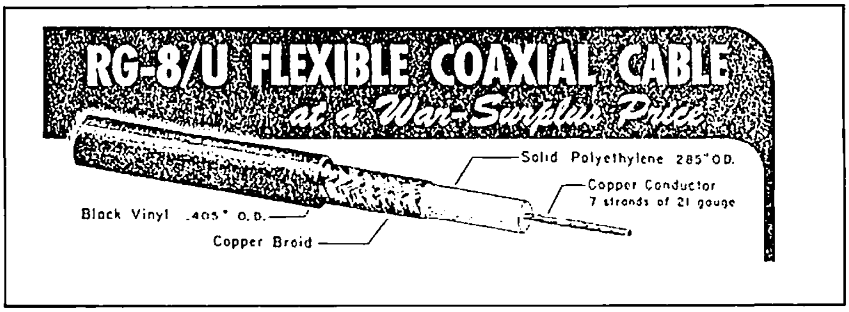
The low-loss coax didn't become available for civilian use until 1946 when the military dumped miles of it on the surplus market (see Figure 1). It sold from two to five cents a foot, depending upon the quantity ordered. In the interim, the Army-Navy RF Cable Coordinating Committee had standardized the cable at 52-ohms impedance, defined its characteristics and had renamed it RG-8/U. (The nomenclature described it in the military cable procurement list: "RG" stood for "Radio Guide," the number "eight" indicated the serial number of the particular cable type, and the "U" stood for "Utility" service.)

A companion, smaller diameter, low-power cable (RG-58/U), was also manufactured during the war in vast quantities. It was available as surplus at a comparable low price. I was so carried away with enthusiasm that I bought a 500-foot roll of each cable type.

It was a whole new ball game for Amateur Radio. The transition from open-wire line to coax was difficult, but it paid important dividends once television became popular and we had to deal with TVI problems. The wartime development of the SWR meter also provided Amateurs with a quick and meaningful readout of antenna operation.

During the fifties, military coax sys-

FIGURE 1



Military surplus coaxial cable sold for from two to five cents in 1946.

tems underwent another major modification. HF and VHF systems were standardized on a 50-ohm impedance level. Because the venerable RG-8/U was a 52-ohm cable, it was obsolete and would be dropped from the military inventory to be supplemented by an equivalent 50-ohm line, RG-213/U. The smaller companion cable RG-58/U (53.5 ohms) was dropped in favor of the interim RG-58A/U (50 ohms) and the new RG-58C/U (50 ohms). That was the end of the matter, or so it seemed.

Today's coax confusion

The military cable change opened the door for the manufacture and sale of "RG-8 type" coax cable of questionable quality bearing a seemingly authentic military acceptance number. Any outfit with a secondhand cable-making machine could grind out cheap RG-8 type cable made to any specification. The unsuspecting purchaser, seeing the look-alike cable at an attractive price, was often conned into thinking he was getting a high-grade product. Not so! Some RG-8/U and RG-8A/U cables are still made to the old military specifications by reputable manufacturers, but a lot of today's RG-8/U isn't.

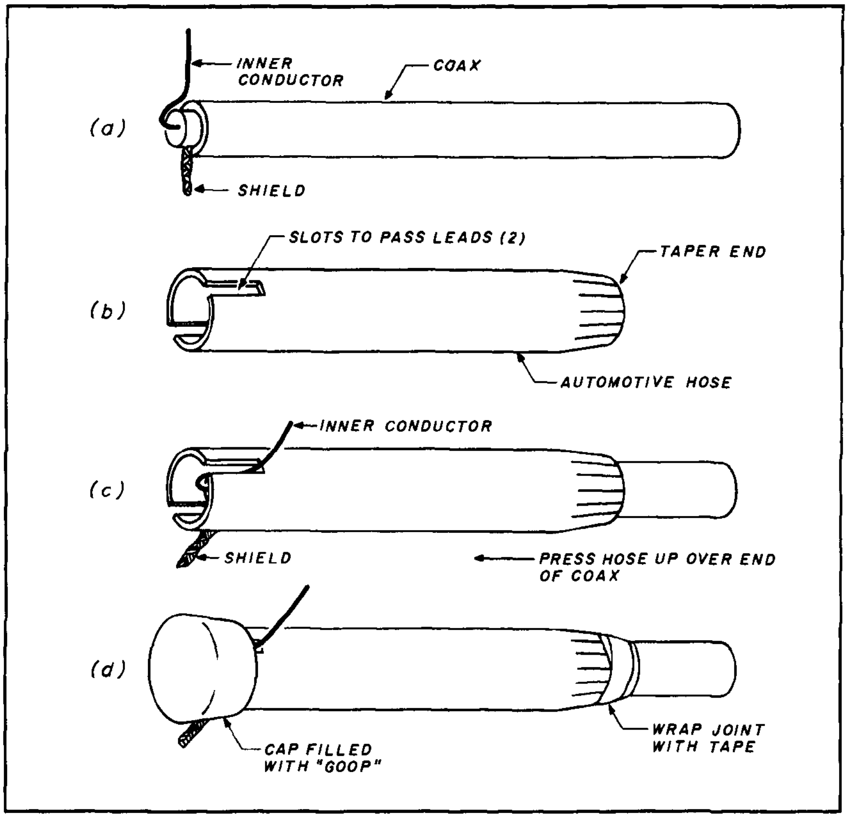
It's easy to make a cheap coax line. Copper creates the major material cost; the cost can be reduced when there is less than the optimum number of fine wires in the outer braid and the braid's weave is looser. The inner conductor can be made of smaller gauge wire, or can have less wires than in the approved coax. The inner insulation can be made of reclaimed or substandard material and the outer jacket can be made of inferior vinyl that has pinholes. The alignment between inner conductor and outer shield may be imperfect. Finally, the rigid inspection and testing given to approved cable types may be entirely absent.

You may not notice results of using cheap coax right away. The first thing you'll find is that it's difficult to place a PL-259 plug on the coax. Good coax has a 97-percent shield coverage. This means that only 3 percent of the shield area is open; the remainder is composed of small copper wires. Less expensive coax may have as little as 75-percent shield coverage, leaving 25 percent of the shield area open. This plays havoc when you try to solder a coax plug on the cable. As soon as the shield wires are hot enough to solder, the polyethylene inner insulation melts and squirts out between the wire interstices, making soldering almost impossible.

It's okay to use this cheap cable at the lower frequencies (like 160 and 80 meters), providing you can solder on the coax fittings. Loss is low and overall shielding is adequate. It's not a good idea to use solderless coax plugs to overcome the soldering problem — but that's another story.

When copper is eliminated in a cheap cable, the cable characteristics change. The 75-percent shield coverage of the cable results in a characteristic impedance of about 60 ohms! Velocity of propagation is also higher and averages 78 percent, as contrasted with 66 percent for the approved line. This can get you into big trouble if you're cutting quarter-wave line sections to formula and not bothering to check line length with a dip meter.

FIGURE 2



Making the coax center insulator. See text for instructions.

In the VHF region, the cheap coax doesn't fully isolate the inner conductor from the outside environment. This diminishes the good electrical isolation quality of the cable.

How can you tell good coax from the cheap stuff? One way is to weigh 100 feet of the line. RG-213/U or good RG-8/U weighs about 11 pounds. The cheaper line may weigh as little as 8 pounds per 100 feet.

"Foam" coax

A new type of coax line appeared on the market in the fifties. The inner dielectric, called "cellular polyethylene," contains many tiny bubbles. The cable is slightly more flexible than an equivalent one with a solid dielectric, and has substantially less loss in the VHF region than common solid dielectric coax. Below 50 MHz, however, there's only a slight advantage in using foam coax for Amateur operations.

A lower loss cable for VHF/UHF use has inner insulation composed of a thick polyethylene insulating thread that wraps around the center conduc-

TABLE 1

Popular types of "50-ohm" coax lines. Approximate weight is in pounds per 100 feet. The cable impedance is Z and the velocity of propagation is V.P. The Military Standard is given where applicable. The inner dielectric is either solid polythylene (P) or cellular polythylene (foam). The percentage of shield coverage is given.

Coax	Belden	Saxton	Weight per 100 ft	Z	V.P.	Conductor inner/outer		Mil. Std.	Dielectric
RG-8/U	8237	8282	11.5	52	66	A	G	JAN-C-17A	P
RG-8A/U	9251	1584	11.5	52	66	A	G	MIL-C-17D	P
RG-8/U type	8214	8284	11.0	50	78	B	G	—	F
RG-8/U type	9208	1583	8.5	57	78	A	H	—	F
RG-8X RG-8M (mini)	9258	8315	4.1	50	78	C	J	—	F
RG-213/U	8267	8409	11.5	50	66	A	G	MIL-C-17D	P
RG-58/U	8240	8289	3.2	53.5	66	D	K	JAN-C-17A	P
RG-58/U type	9201	1589	2.9	53	66	D	L	—	P
RG-58A/U	8259	7290	2.9	53	66	D	L	JAN-C-17A	P
RG-58C/U	8262	1591	2.9	50	66	E	K	MIL-C-17D	P
RG-58C/U	9203	—	2.9	50	66	E	K	MIL-C-17E	P
RG-58/U type	8219	1600	2.9	50	78	F	M	—	F

The inner conductor is defined as:

A—13 AWG 7 strands no. 21 solid copper
B—11 AWG 7 strands no. 19 solid copper
C—16 AWG 19 strands no. 29 solid copper
D—no. 20 solid copper
E—20 AWG 19 strands × 0.0071 diameter solid copper
F—20 AWG 19 strands no. 32 solid copper

The outer shield is defined as:

G—Bare copper, 97-percent shield coverage
H—Bare copper, 80-percent shield coverage
J—Bare copper, 95-percent shield coverage
K—Tinned copper. 95 percent shield coverage
L—Bare copper, 78-percent shield coverage
M—Tinned copper, 96-percent shield coverage

tor. The outer shield is made up of two layers. The inner layer is a closed aluminum wrapping; the outer layer is a tinned copper braid that has 60 to 97-percent coverage. Either combination provides 100-percent cable coverage.

In addition to these common cables, you can purchase specialized cables for CATV use with a nominal impedance of 75 ohms. These have limited applications for general Amateur service.

I've summarized some useful cables for Amateur Radio operations in **Table 1**. The cables are cross-referenced to Belden and Saxton catalog numbers for your convenience.

A cheap and effective center insulator

Do you need an inexpensive center insulator for a Field Day dipole? You can buy several different makes, but here's a design you can build yourself for just a few pennies. The idea originated with Lloyd Bensen, W9YCB. The device is light, waterproof, and made of easily obtainable materials (**Figure 2**). Lloyd uses his insulator on a beam because he had problems with water entering the line.

The heart of the assembly is a 4-1/2" length of 1/2" (inner diameter) automotive hose. Taper one end of the hose with a razor or sharp knife, and slot the other end to receive the wires of the coax cable. Slide the hose over the cable as shown, with the slotted end facing the end of the cable.

Prepare the cable by fanning out the braid and unbraiding about 2" with a pointed tool. Twist this portion of the cable into a tight pigtail. Now remove the inner insulation, leaving only a protective collar about 1/8" long between the inner conductor and the outer braided pigtail.

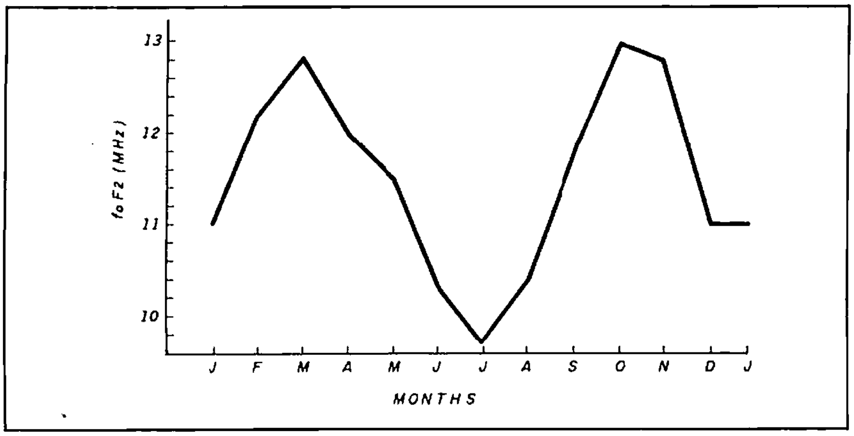
Bend the coax conductors into the shape shown in the drawing and tin them. Extend the tinning back to the insulating material. Tin the exposed portion of the outer braid all around the cable. Finally, cut the conductors back leaving leads about 3/4" long.

Press the hose up so the tinned conductors drop into the slots you cut. Taper the slots slightly for a tight fit.

Now weatherproof the end of the cable. Lloyd recommends using a plastic cap from a hardware store or home service center. A cap with about 5/8" inner diameter slips nicely over the hose. Cover the end of the cable and the inside of the cap with semi-liquid insulation before attaching the cap. Lloyd used "Sportsman's Goop" from a sporting goods shop. (You could fill the cap with quick-setting epoxy instead.) Press the cap over the hose and the end of the cable and carefully wipe away any excess goop or epoxy around the conductors.

Wrap the tapered end of the hose with vinyl tape. Extend the tape an inch

FIGURE 3



Seasonal change in ionospheric reflection averaged monthly since 1946, as observed by KH6SB at the Maui (Hawaii) Ionospheric Station. Measurements were made during daylight hours (1100 to 1700 HST) on vertical angle of reflection. Maximum Usable Frequency (MUF) is about three times higher than measured reflection frequency (FoF2) shown. The MUF has been highest during months of March, October and November, regardless of sunspot cycle number. Low point of the MUF is reached in July. (Measurements taken mid-month intervals.)

or two down the coax line. This prevents moisture from entering the end of the hose and being drawn up into the coax by capillary action.

It takes almost as long to read this as it does to make the joint. Try one of these simple devices out on your next Field Day antenna!

Radio conditions getting better!

In my September 1988 column I discussed ionospheric readings made at the Maui, Hawaii Ionospheric Station by Steve, KH6SB. One of the charts shown depicted the average value of F2 reflection measured by a pulsing technique on a vertical path. The chart was for a 24-hour time period, averaged each month since 1946.

Figure 3 shows the same measurements plotted over a 7-hour period, corresponding to the daylight hours. This provides a more realistic picture as the higher frequency bands are usually closed to F2 skip during the hours of darkness.

The chart is especially meaningful as the sunspot cycle continues to rise. It shows that DX conditions are at their best during mid-February through mid-May. A second period of good DX activity falls during the period of mid-September through mid-November.

DX conditions during the winter aren't bad, but they are limited by the short span of daylight. Summer DX conditions, on the other hand, are poor from mid-May through mid-September. If you want to take a vacation or work on your antenna, this is the time to do it!

The "Dead Band" contest

I want to express my appreciation to all who write me in regard to these little tests of expertise. I appreciate your support and kind remarks. I'm sorry I can't reply to each of you in person. I'd like to extend a hearty "thank you" to all who took the time to write.

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Ham Notebook

A Big Video Monitor for Packet Demonstrations

Packet operators are often called upon to give demonstrations to public officials or Amateur Radio groups. Because of the small screen, everyone has to crowd around to see what's going on. Small computer screens create difficulties for sight-impaired hams as well.

There are large-screen (and even projection) TVs available, but most equipment designed for off-the-air television reception has only a 4.5-MHz video bandpass and is unable to display the "normal" 80 columns. (Commodore and Apple default to 40 columns because many people use ordinary television sets as monitors.) The serious computer user needs a monitor with a video bandpass of at least 12 MHz.

There is a family of excellent large-screen monochrome video monitors that meet the 12-MHz video bandpass requirement. These are the 19-inch Motorola M5000s and 23-inch Motorola M7000s made for use as flight annunciator displays at airports. Unfortunately, they are no longer manufactured, but service literature and parts are still available and the monitors do show up at computer and ham flea markets.

A frequently asked question is: "Will my computer have enough output to drive a large-screen monitor like that?" Luckily, this is no problem. A monitor requires two inputs, power and signal. While the power requirement may go up (these units require 110 watts), the signal requirement is independent of screen size.

The M5000 and M7000 require 117 volts AC and a "composite" video signal (the normal output from most computers like the Apple or Commodore). They are specified to have a horizontal sweep frequency of 15,750 ±500 Hz with a vertical of 50 or 60 Hz.

It would probably be wise not to share this tip with our non-ham computer friends, or they'll dry up the entire supply and there won't be enough left for us...

David McLanahan, WA1FHB

A Simple Infrared Detector

My house is full of remote gadgets. The TV, VCR, and other assorted goodies all respond to commands issued on invisible rays of infrared light. Even my ham shack hasn't been spared; optical interrupters have replaced multisection tuning capacitors in receivers and transceivers. For most of us, trouble-shooting these devices has been limited to changing the battery and hoping for the best.

This project is designed to detect infrared light. It can be used in conjunction with a scope to verify that encoding information is present.

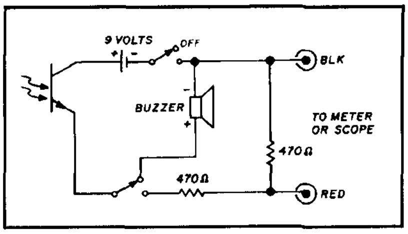
I enclosed my detector in a 4-3/4×2-1/2×1-1/16 plastic case, but the circuit is simple enough that you can breadboard it when the need arises. I found all the parts at the local Radio Shack for under $15. Construction isn't critical; I mounted all of the components on the case's front panel and used point-to-point wiring.

The circuit is shown in **Figure 1**. To keep things portable, you can use a piezoelectric buzzer in place of the scope for infrared detection. The encoded binary information emitted from a hand controller will modulate the buzzer's tone. I mounted the phototransistor in an LED bezel. You can also install it in the barrel of an old pen (with a length of RG-162 going back to the remaining circuitry) for probing around infrared sources in shaft encoders and other tight areas.

The detector saturates when used outdoors during the daytime. A small 3 or 4-inch tube placed in front of the phototransistor will reduce incidental pickup.

Peter J. Bertini, K1ZJH

FIGURE 1



The circuit for the simple infrared dectector.

PARTS LIST

Quantity	Description	Radio Shack part number
1	*IR phototransistor*	*276-145*
1	*piezo buzzer*	*273-065A*
2	*SPDT switches*	*275-603*
2	*470 ohm 1/2 watt*	*271-019*
1	*9-volt battery*	*23-464*
1	*battery connector*	*270-325*
1	*battery holder*	*270-326A*
2	*binding posts*	*274-661*
1	*plastic case*	*270-222*
1	*LED bezel*	*276-080*

THE BATTLE OF THE BEAMS
PART 1

By D. V. Pritchard, G4GVO, 55 Walker Dr., Leigh on Sea, Essex SS9 3QT, England

1940...Now, nearly 50 years from those near-disastrous days, how many of us remember (or even know of) the debt of gratitude owed to one man who confounded the radio experts and overcame officialdom to earn Churchill's praise as the man who "broke the bloody beams" — who went on to unravel the secrets of German radar and Hitler's "V weapons," the V1 pilotless flying bomb (the "doodlebug") and the V2 rocket?

Born in London in 1911, R. V. Jones was educated at St. Jude's, Herne Hill, and later at the Elementary School in Sussex Road, Brixton, where he won a scholarship to Alleyn's School, Dulwich. Awarded an Open Exhibition in 1929 to Wadham College, Oxford, he worked in the Clarendon Laboratory under Professor Lindmann (later Lord Cherwell and Winston Churchill's wartime Scientific Adviser), where he turned his talents to infrared detection — an interest he was to pursue for the next 30 years.

In 1939, he was appointed Scientific Officer to the Military Intelligence Service (MI6) to find out what the Germans were doing in the way of applying science to warfare. In early 1940, he came to believe that they had a radio-navigation system by which they hoped to bomb accurately at night.

Knickebein—the crooked leg

From captured documents found in crashed German aircraft he came across the word *Knickebein*, or "crooked leg." The Germans' code names were informative — this one even sounded like a beam. But what kind was it?

Then two prisoners of war were overheard to speak of something called *X-Gerät*, or "secret apparatus;" evidently it was something used in an aircraft, and involved radio pulses. A thriller could hardly have a more intriguing title, but what was X-Gerät— and was it the same as Knickebein? Deeply interested, Jones pressed his Intelligence sources for more information and in March was rewarded with the navigator's notes from a shot-down Heinkel. *Navigational Aid: Radio Beacons working on Beacon Plan "A." Additionally from 0600hr Beacon Dühnen. Light Beacon after dark. Knickebein from 0600hr on 315°.*

Shortly afterwards, a cooperative prisoner said that Knickebein was a beam so narrow and exact that two of them could pinpoint a target with an accuracy of less than a kilometer. He also added that Knickebein was in some ways similar to X-Gerät, assuming that we were familiar with both systems!

From the wreck of another Heinkel, a diary was rushed to Jones. It read: *March 5. Two-thirds of flight on leave. Afternoon training on Knickebein, collapsible boats, etc.*

By this time, the cryptographers at Bletchley Park had performed a near miracle by breaking the German *Enigma* code. One of the intercepted messages from a German aircraft was sent to Jones: *Knickebein, Kleve, is confirmed at position 53°24' north and 1° west.* This meant that the aircraft had reported receiving the beam a few miles south of Retford in Nottinghamshire, and Kleve (where Anne of Cleves came from) was on the nearest German soil to England.

But, clearly, there had to be two beams: one along which the bomber flew, and another one — a marker beam — to tell the pilot when he was approaching his target. Evidence of this second beam arrived a few days later in yet more salvaged papers from a crashed Heinkel. *Long-range Radio Beacon: Knickebein (Bredstedt) 54°39', 8°57', Knickebein (Kleve) 51°47'5", 6°6'.*

So Bredstedt in Schleswig-Holstein was the source of the second beam!

Amateurs and experts

Obviously beams less than a kilometer wide at well over 300 km called for very high frequencies — possibly something in the centimetric region. And although this part of the spectrum was in some use at the time, the power generated by valves then available was very low. Certainly the German system suggested they had overcome the problem. (It was only later that we discovered that German radar had been operating on 50 cm since about 1930!)

However, Rowley Scott-Farnie, G5FI (then a signals officer in RAF Intelligence), showed Jones a report by T. L. Eckersley (the country's leading propagation expert), in which Eckersley had computed the possible range of a 20-cm transmitter sited in the Hartz Mountains. If the calculations were correct, the signals would bend round the earth and might well be heard by a bomber at 20,000 feet over England. This

information, together with the evidence he had already collected, prompted Jones to alert Professor Lindemann to the possibility that the Germans had a narrow-beam system for bombing the country. Lindemann naturally countered with the objection that the frequencies they would have to use could not possibly bend round the earth, but Jones produced Eckersley's calculations and told him that indeed they could.

But how were the Germans doing it? Inspection of captured aircraft revealed nothing unusual and the radio equipment seemed perfectly normal — certainly nothing in the way of centimetric receivers. He pressed for yet more information, especially from the prisoner-of-war interrogation centers. Did their aircraft carry special receivers for beam reception? Had we missed something?

Quite correctly the prisoners admitted nothing. But at one center a prisoner was overheard to tell his friend that no matter how hard we looked for the equipment we would never find it. This startled Jones, for it implied that it was under our very noses and therefore we would never see it. Methodically he sifted through the captured equipment, but the only item that fit the bill was the receiver marked E Bl 1 (Empfänger Blind 1) — Blind Landing Receiver Type 1 — which was used by both the RAF and the Luftwaffe for blind landing on the Lorenz Beam System.

The Lorenz System, however, only had a range of about 8 km at best, unless the Germans had somehow dramatically increased its range. Knowing that Farnborough had evaluated the equipment, he inquired if there was anything unusual about the receiver.

"No," came the reply "But since you mention it, the receiver is many times more sensitive than they would ever need for blind landing."

Could that be it! Dr. Jones spoke to Lindemann, who drafted a note to Churchill. He wrote: *"There seems some reason to suppose that the Germans have some type of radio device with which they hope to find their targets."*

Churchill initialed the note and sent it to the Air Minister, adding: *"This seems most intriguing and I hope you will have it thoroughly examined."*

A committee of inquiry was formed and Squadron Leader R. S. Blucke was put in charge of flying operations. Three Ansons were fitted with suitable receivers and flown by Lorenz-trained pilots. Rowley, G5FI, told Jones that the German preset frequencies were likely to be 30, 31.5, and 33.3 MHz, and sure enough a few days later a scrap of paper recovered from yet another crashed aircraft read: *Knickebein (Kleve) 31.5.*

On June 20 a Heinkel was shot down. The radio operator had bailed out, had torn his notes into shreds, and was actually burying them when he was captured. An Intelligence NCO unearthed them, gummed them together, and sent them to London: *VHF. Knicke 54°38'7"N, 8°56'8"E, 51°0'30"N, Eqms., Stollberg 30 mc/s. Kleve 51°47'N, 6°2'E, 55°N, 2°Eqms., 31.5 mc/s.*

This seemed to confirm the existence of another Knickebein installation at Stollberg and in Schleswig-Holstein. It also confirmed Scott-Farnie's guesses about the frequencies. Yet after two flights the Ansons failed to find the beams.

Was Jones wrong after all? Many thought so. Sir Henry Tizard was skeptical (and fell from Churchill's favor as a result), Air Chief Marshal Dowding was doubtful, and Air Chief Marshal "Bomber" Harris was scathing. Other military and scientific brains looked askance at the young man who questioned established wisdom. Then, suddenly, Jones was summoned to a meeting at Downing Street.

Thinking the message was one of Scott-Farnie's practical jokes, he arrived half an hour late to find the meeting already in progress. A galaxy of talent confronted him. Churchill sat on one side of the table flanked by Lindemann on his left and Beaverbrook on his right. Facing them was Sir Archibald Sinclair (the Air Minister), Sir Cyril Newall (Chief of the Air Staff), Sir Henry Tizard, Watson-Watt, and Portal and Dowding (Commanders-in-Chief of Bomber and Fighter Commands). Breathing his apologies to the Prime Minister, Jones took his place at the end of the table. An argument was taking place — did the beams exist or didn't they? Soon Jones realized that nobody in the room knew as much about the matter as he did. Suddenly Churchill snapped a question at him, and feeling he couldn't answer it out of context Jones said, "Would it help, sir, if I told you the story right from the start?" Churchill seemed somewhat taken aback but then replied, "Well yes, it would."

For the next 20 minutes Jones outlined his evidence. As he later recalled *"...although I was not conscious of my calmness at the time, the very gravity of the situation somehow seemed to generate the steady nerve for which it called. Although I was only 28, and everyone else around the table much my senior in every conventional way, the threat of the beams was too serious for our response to be spoilt by nervousness on my part."*

When he had finished, an air of incredulity filled the room. Sir Henry Tizard demanded to know why the Germans should use a beam anyway, assuming such a thing was possible. Our own pilots found their targets very well by astro-navigation. (They didn't! *Author.*) Others round the table seemed doubtful. But Churchill was convinced and asked Jones what should be done.

"I told him that the first thing was to confirm their existence by discovering and flying along the beams for ourselves, and that we could develop a variety of countermeasures ranging from putting a false cross-beam for making the Germans drop their bombs early, to using forms of jamming ranging from crude to subtle."

With a typical "Let this be done at once!" Churchill then turned round and tore a strip off the Air Ministry for their tardiness.

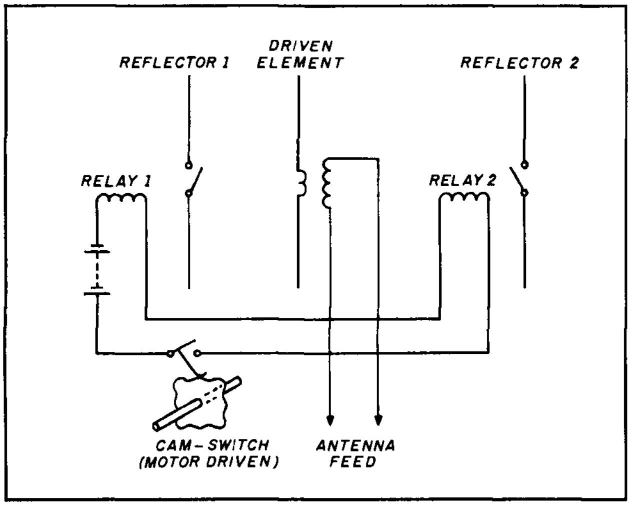
And expert amateurs

Elated at having convinced the Prime Minister, Jones dashed away to attend a conference in the office of the Director of Signals, Air Commodore Nutting, to discuss the possibility that the Germans might exploit pulse techniques as nagivational aids. T. L. Eckersley was to give evidence. However, because Eckersley disagreed with Jones's findings, the subject reverted to Knickebein.

But what about those propagation calculations? Oh, those! Eckersley pooh-poohed them; he didn't believe them himself. He was only trying to demonstrate how far the signals *might* go under certain conditions. He thought he had been stretching theory too far, and doubted if signals in the 30-MHz band would curve round the earth.

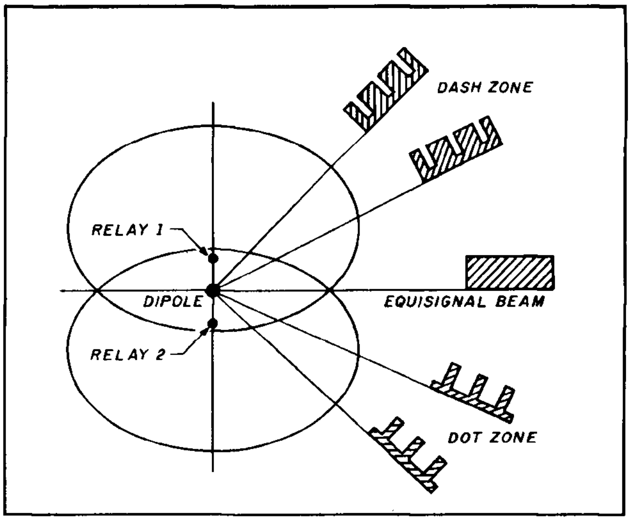
The Ansons had failed to detect the beams during their previous flights and another one was due that evening. In order to cancel it the Principal Deputy-Director of Signals,

FIGURE 1



The principle of the operating reflectors.

FIGURE 2



The principle of the Lorenz beam system.

Group Captain O. G. Lywood, picked up the phone saying, "Well, we have here the greatest expert on radio propagation in the country and he says the beam theory is all wrong. We've wasted a lot of time and let's not waste any more. This evening's flight should be canceled!" But Dr. Jones stood his ground. Pointing out that Eckersley's evidence had neutralized itself because he had said one thing a few months before and now said something quite different, and that enough evidence already existed to convince him, he demanded that Eckersley's statement should be ignored. He also told Lywood that if the flight was cancelled he would "jolly well let the Prime Minister know who had countermanded his orders." Lywood backed down.

From the Chair, Air Commodore Nutting demanded: "And what do we do if we find the beams?" Quietly Jones whispered to Rowley Scott-Farnie, "Go out and get tight!"

Black night and bright dawn

Dr. Jones went home to spend one of the most miserable nights of his life. *"Had I, after all, made a fool of myself and misbehaved so spectacularly in front of the Prime Minister? Had I jumped to false conclusions? Had I fallen for a great hoax by the Germans? Above all, had I arrogantly wasted an hour of the Prime Minister's time when Britain was about to be invaded or obliterated from the air?"*

It was a beautiful summer's night — the shortest night of a terrible year for Britain — when Flight-Lieutenant Button and Corporal Mackie climbed aboard their Anson and flew over the area between Huntingdon and Lincoln. Neither had been told the Knickebein story, but merely to search for beams with Lorenz characteristics. Suddenly on the Hallicrafters receiver they heard signals on 31.5 MHz. Dots!

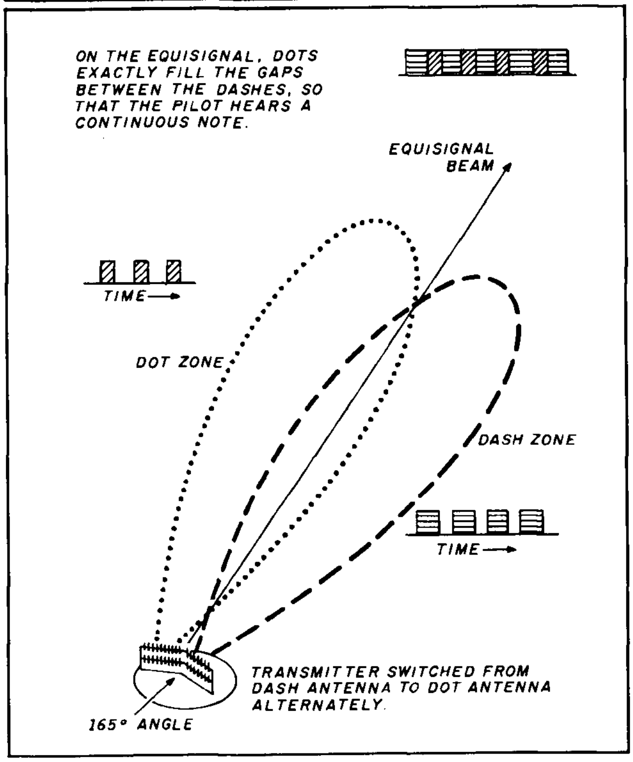
The aircraft swung to the north. Still dots. Then a continuous note, and later, as expected, a zone of dashes. When the dashes ceased, Button and Mackie began intently to plot the beam. The following afternoon Button's report was on Jones's desk:

1. There is a narrow beam (approximately 400 to 500 yards wide) passing through a position 1 mile south of Spalding, having dots to the south and dashes to the north, on a bearing of 104°(284°T).

2. The carrier frequency of the transmissions on the night of 21/22 June was 31.5 mc/s, modulated at 1150 cycles and similar to Lorenz characteristics.

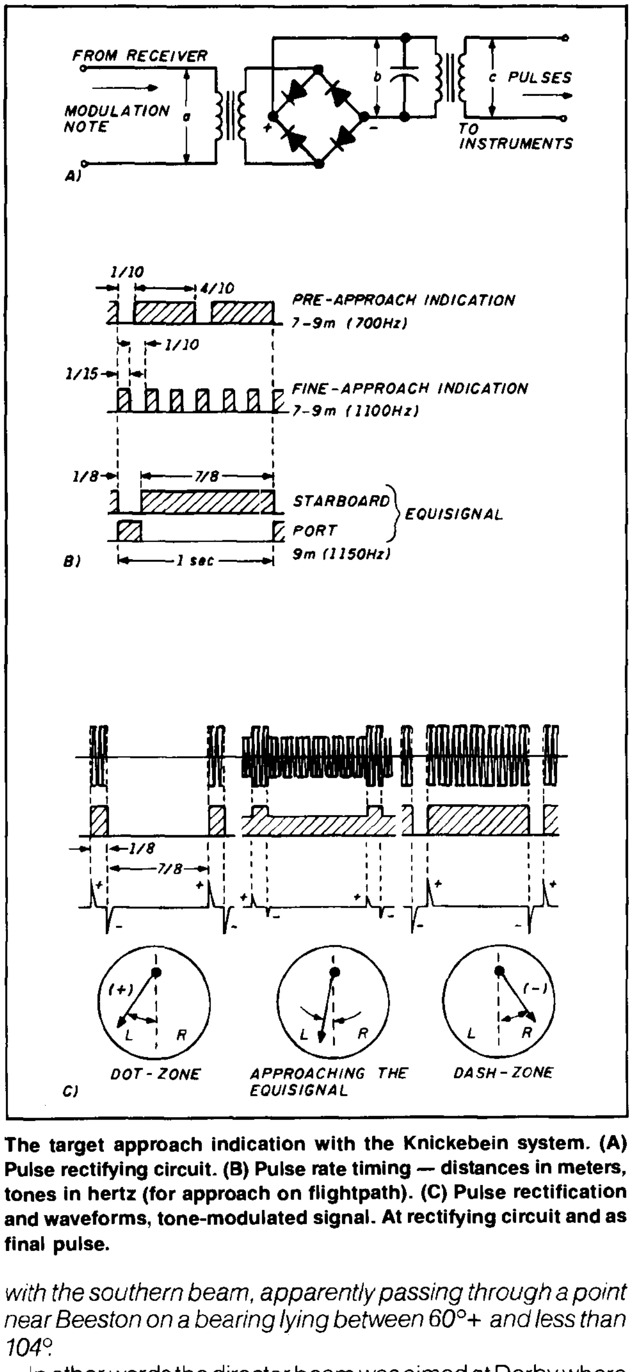
3. There is a second beam having similar characteristics but with dots to the north and dashes to the south synchronized

FIGURE 3



The principle of the Lorenz (Knickebein) beam.

FIGURE 4



The target approach indication with the Knickebein system. (A) Pulse rectifying circuit. (B) Pulse rate timing — distances in meters, tones in hertz (for approach on flightpath). (C) Pulse rectification and waveforms, tone-modulated signal. At rectifying circuit and as final pulse.

with the southern beam, apparently passing through a point near Beeston on a bearing lying between 60°+ and less than 104°.

In other words the director beam was aimed at Derby where the Rolls Royce factory produced engines for the RAF — as Jones had suspected. The impact of Bufton's report on the meeting that afternoon may well be imagined. Jubilation was in the air. Even "Daddy" Nutting was skipping round the room in delight. All doubts were now dispelled and countermeasures could go ahead urgently.

In the midst of the revelry Scott-Farnie buttonholed Jones: "Remember what you said yesterday?"

So they bowled across to a pub to celebrate.

The Lorenz System

In 1932, Dr. E. Kramar of the German Lorenz Company began to develop a high-frequency blind landing system on pre-set frequencies between 30 and 33.5 MHz, continuous wave modulated at 1150 Hz. The beacon transmitter and its associated antenna system stood at the end of a runway and had a range of 3 to 5 km (sometimes more depending on conditions) even though the transmitter developed 500 watts. The output was fed to a single dipole, to the left and right of which and at a quarter-wave spacing was a single reflector cut at its center point. A relay was used to alternately close and open the reflector, as shown in **Figure 1**, whereupon a beam was generated at an angle left and right of the driven element composed of dots to one side and dashes to the other (see **Figure 2**). These alternating beams partially overlapped each other centrally to give a narrow zone of about 3° angle in which the dots and dashes were heard as a single note, telling the pilot he was on the correct approach (see **Figure 3** and **4**). A simple presentation unit was also provided in the cockpit which showed the course deviation on a meter; a form of range measurement was furnished by an S-meter arrangement.

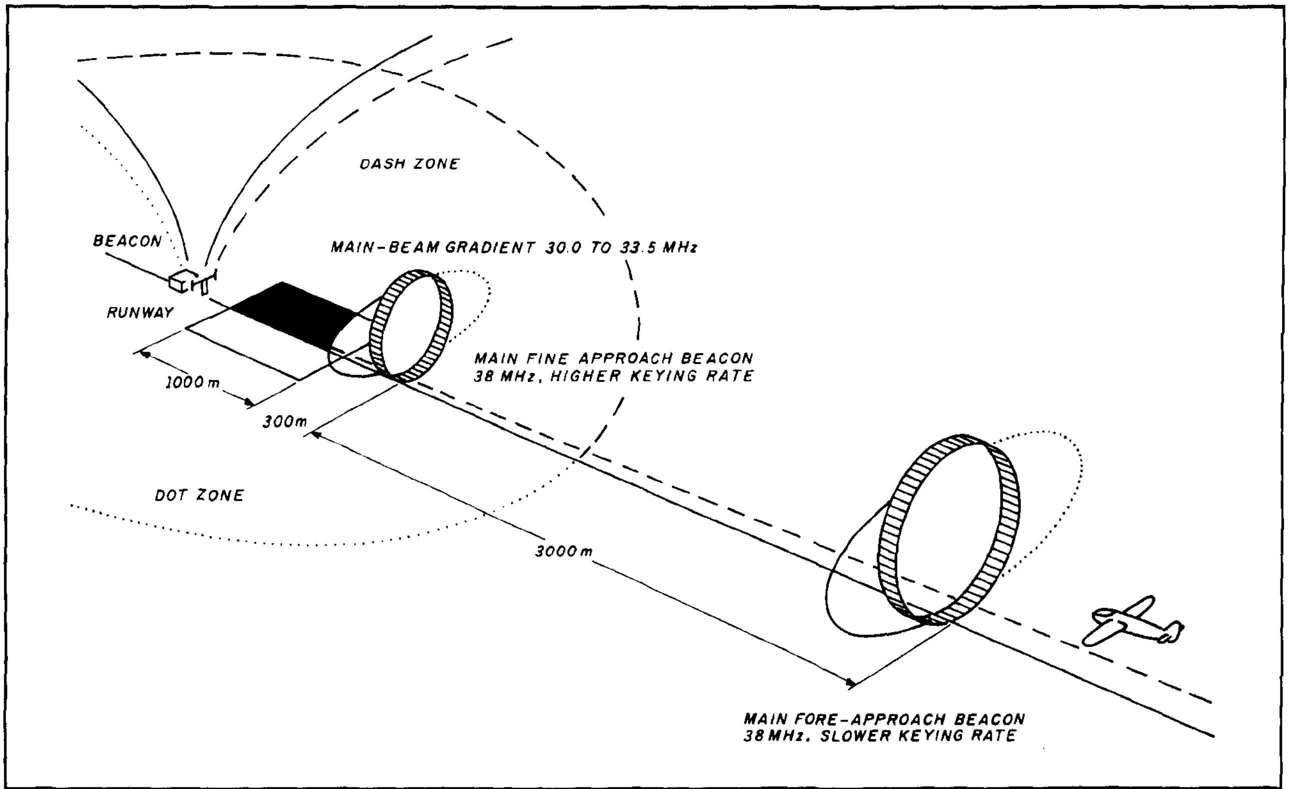
Two additional transmitters were employed to aid landing (**Figure 5**). At a point 3 km before the runway was an early-approach system on 38 MHz with a power of 5 watts, but having a slower keying rate and a lower modulation note. The second system was comprised of a transmitter at 300 meters before the runway, with a higher key rate and modulation tone. Both these systems operated a lamp on the presentation unit to give further visual indication.

The accompanying aircraft receiver was known as the EB 1 (Blind Landing Receiver 1), which was developed from the earlier EBE receiver. The system was made available to Lufthansa in 1934 and the aircraft were fitted with vertical rod antennas, usually quarter-wave whips. Later, the Luftwaffe produced a specification for what was to be called the Blind Landing System FuB 1, and which required two separate receivers — the EB 1 for signals in the range 30 to 33.3 MHz, and the EBL 2 for 38 MHz. All multi-engined aircraft of the Luftwaffe were fitted with these up to 1941.

As war seemed inevitable, Dr. Lohmann of Telefunken developed a much larger system which was called FuS An 721 in 1938. This was an antenna array of metal girders 30 meters high and 90 meters long which revolved on a circular iron track. In the middle was a 50-watt transmitter for 30 to 33.3 MHz. The framework supported 16 vertical wire dipoles and reflectors and was arranged as an angle of 165° (looking down on the array), so that eight two-element antennas were in each leg of the framework. From this "broken neck" appearance, *geknickten* in German, came the code name Knickebein.

Details of the transmitters and receivers used are, unfortunately, no longer in existence. However, the antenna lobes were similar to those shown in **Figure 6**, except that the narrow equisignal zone was ±0.3° wide and the keying of the dash/dot system had a ratio of 1:7. The improved receiver, another mark of the EB 1 known as the Fu Bl 1, could receive the beam at a range of 500 km and a height of 6500 meters. The principle was that the main beam was directed at a tar-

FIGURE 5



The principle of the Lorenz blind landing system.

get, and the pilot knew he was on course when a continuous note appeared in the receiver. If he strayed to the left, a preponderance of dots was heard; a swerve to the right produced dashes.

By 1940, ten smaller versions of Knickebein had been built which required only a circular track of 45 meters in diameter. Each leg of the angled frame contained only four sets of vertical two-element arrays, which were broadbanded to tune between 30 and 33.3 MHz by construction from wide-diameter tubing. The range was almost the same in practice as the large Knickebein, although the main beam width was wider at ±0.6°.

As already mentioned, when in use the main beam was directed at the target, and at a predetermined point some distance before the target was reached it was overlapped by a second beam on a different frequency. This told the pilot his distance in kilometers from his objective. **Figure 6** shows the method in more detail.

Although no details remain of the receivers used, it is known that they were t.r.f types and, as will be seen later, very susceptible to jamming. For this reason a Dr. W. Kloepfer of Lorenz developed a superhet, the EBL 3 H, which needed only slight preparation as it used the same p.s.u. as its predecessor and fitted the same cabinet. This was tunable over a number of channels from 1 to 34 in the spectrum 30 to 33.3 MHz, and could receive the Knickebein transmissions at the same height and range as the earlier model.

Pulling the Crooked Leg

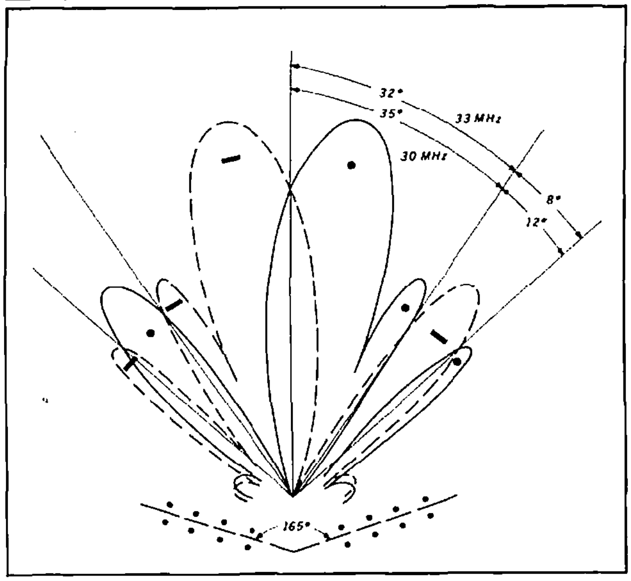
A special unit was set up to counter the beams (which were code named *Headaches*) under the command of Wing Commander E. B. Addison of No. 80 Wing at Radlett. The technical design of the countermeasures was the responsibility of Dr. Robert Cockburn of the Telecommunications Research Establishment at Worth Matravers. Both organizations were accorded the highest priority.

Receivers were placed on top of the masts of certain stations of the Chain Home RDF (radar) system, and the unlucky operators in these dizzy crow's-nests were connected by telephone with Fighter Command Headquarters at Bentley Priory.

Professor Jones records how he, too, spent a night on top of one of these towers — listening to the signals which Eckersley had said could not be heard even by a bomber at 20,000 feet over England. *"When about dusk the German beams were switched on, the men in the towers would be able to pick them up and let us know, for instance, if a beam was going between tower 'A' and tower 'B.' That would give us a clue to the beam's position, and one of our chaps would go up in an Anson and fly back and forth until he picked up the beam, which could then be plotted."*

The first jammers were diathermy sets used by hospitals to cauterize wounds. These were requisitioned and tuned to the Knickebein frequencies. Although they only emitted a mush

FIGURE 6



The antenna pattern of the Knickebein array.

of signals, it was thought that they had some effect on the beams. Installed mainly in police stations, they were switched on when ordered by No. 80 Wing.

Fortunately we had acquired the Lorenz license before the war, so Lorenz transmitters were modified and strategically placed, as were "Meacons," or mock beacons. The Luftwaffe, with more than 80 radio beacons at their disposal in Germany and occupied Europe, began to find radio navigation an ever-increasing problem. But it was Cockburn's jammers (code named *Aspirins*) that were most effective. Immensely powerful, they flooded the beams with dashes and the German pilots, flying into their own dash zones, would steer to find the equisignal only to find Cockburn's dashes. They would continue turning until they found a dot zone (and Cockburn's dashes), which often synchronized into a false equisignal note. After they found themselves flying round in circles during bombing raids for a few weeks, they came to realize that we had found and jammed their system. We had, in fact, "pulled the crooked leg." An additional bonus lay in the fact that it was several months before the German pilots had the courage to tell Goering that Knickebein was useless.

Had the system worked successfully, a number of bombers could have put bombs *every 17 meters* into a selected target. As it was, our cities suffered severe mauling from the Luftwaffe. Who knows how much worse the loss of life and property would have been but for the efforts of a young physicist who refused to believe the experts, and courageously challenged his superiors.

Today one wonders how many Londoners and citizens of our other major cities have heard of Professor R. V. Jones. hr

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LINEAR TUNING WITH A WAR SURPLUS CAPACITOR

Precision dials based on frequency measurements

By John Pivnichny, N2DCH, 3824 Pembrooke Lane, Vestal, New York 13850

Modern commercial transceivers have linear tuning scales. Whether these scales are analog or digital, each revolution of the main tuning knob covers a fixed number of kilohertz across the tuning range. Linear analog tuning is done with specially designed capacitors that aren't available to Amateur transceiver builders. I think a first-class homebrew design should have this capability, and this article explains how to add it inexpensively.

Capacitor fundamentals

Consider a variable capacitor constructed as shown in **Figure 1A**. Capacitance change is made by a horizontal movement rather than a rotary motion. As the movable plate slides to the right by an amount X, the capacitance at the terminals (C) decreases an amount ΔC from its value C_0, which is present when the movable plate is at its left-most position (fully meshed).

In equation form:

$$C = C_o - \Delta C \quad \textbf{(1)}$$

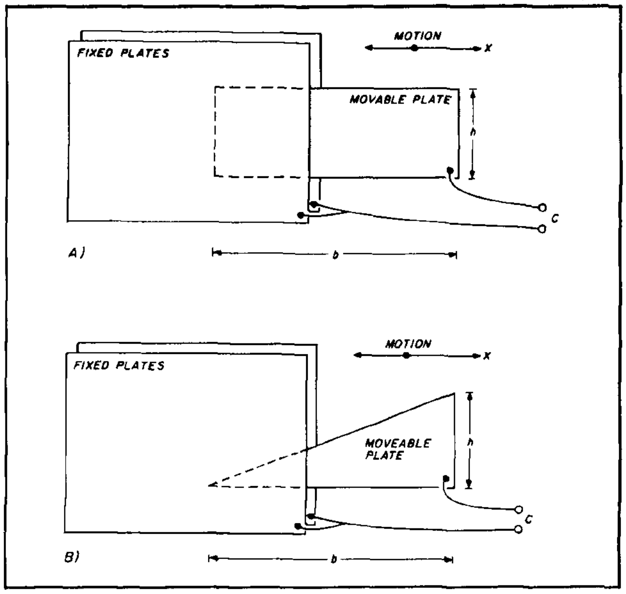
or $C = C_o - kX$ **(2)**

The constant k represents the change in capacitance per unit movement in X. **Equation 1** is plotted in **Figure 2A** and:

$$k = \frac{C}{X} \quad \textbf{(3)}$$

The amount of change depends upon the size of the plates and the spacing. But because the movable plate has straight sides, the value of k is fixed across the whole tuning range. This is linear capacitance and it's well known that it won't produce linear tuning. The high frequencies will be compressed at the right edge of the dial.

FIGURE 1



Capacitor plates are moved laterally to produce a change in capacitance. A and B are discussed in the text to show effect on capacitance with plate movement.

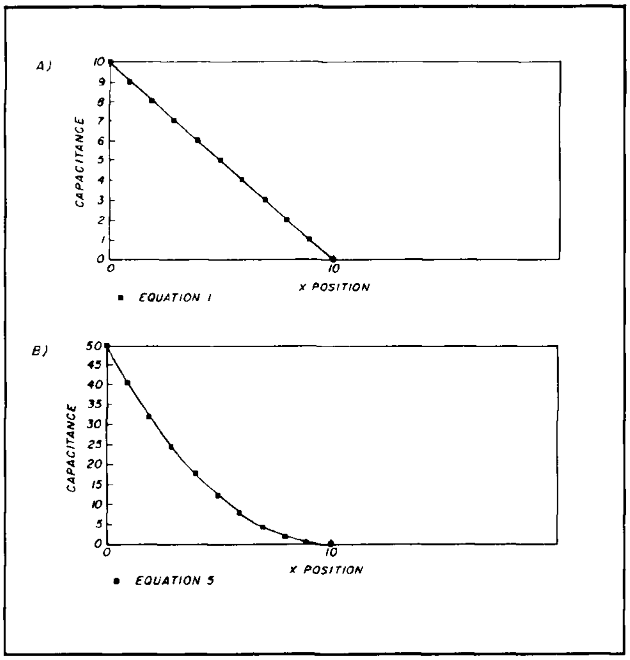
Obviously the capacitance is changing too quickly at the high-frequency end of the dial. **Figure 1B** shows an improvement. The rectangular movable plate has been replaced by a triangle of height h and base b. The terminal capacitance now depends upon the area of the meshed triangle. The triangle's base and the height change with horizontal motion X. In equation form:

$$C = 1/2\,(b - X)\,(h - \frac{h}{b}X) \quad \textbf{(4)}$$

$$C = 1/2\,(bh - 2hX + \frac{h}{b}X^2) \quad \textbf{(5)}$$

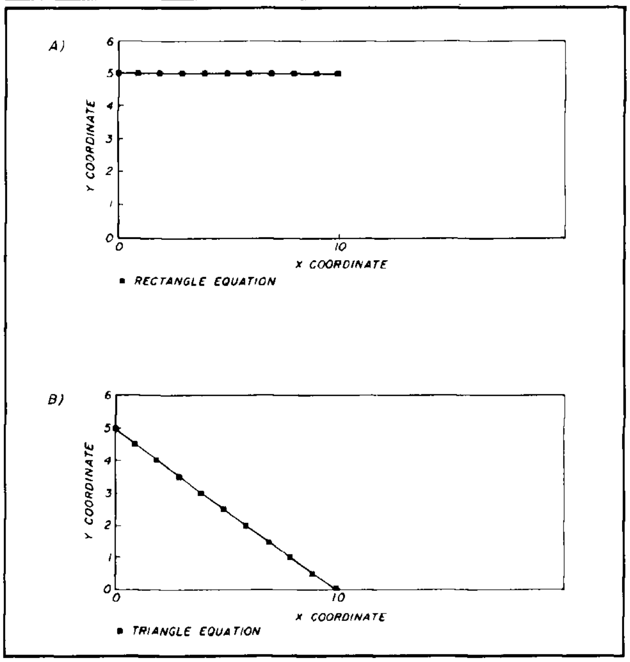
Equation 5 (plotted in **Figure 2B**) shows that the capacitance changes more slowly at the high-frequency end of the dial, due to the parabolic shape represented by **Equation 5**.

FIGURE 2



Data for rectangular, A, and triangular, B, capacitor plates. Capacitance scale is arbitrary.

FIGURE 3



***Equations* 6 and 7 are plotted in A and B and represent capacitor-plate shapes of *Figure 1*. Shown are the negatives of the slopes of the data in *Figure 2*.**

Unfortunately, this isn't exactly the curve necessary for a linear frequency scale, but now you have the background to get there.

Think of the top edge of the movable plate as representing an equation with the X axis starting at the right edge and going left. This reversal is necessary because frequency increases as capacitance decreases. The Y coordinate is given by the height of the variable plate at each X coordinate.

The equations are:

rectangle: $Y = h \text{ for } 0 < X < b$ **(6)**

triangle: $Y = h - \frac{h}{b} X \text{ for } 0 < X < b.$ **(7)**

They are shown in **Figure 3A** and **3B** and represent the plate shapes of **Figure 1** — except for that of the X axis in its normal position (i.e., going right).

Figure 3 gives the slopes (actually the negatives of the slopes) of the data plotted in **Figure 2**. You can get the shape of the movable plate for any capacitance equation of **Figure 2** by taking the slope, as shown in **Figure 3**.

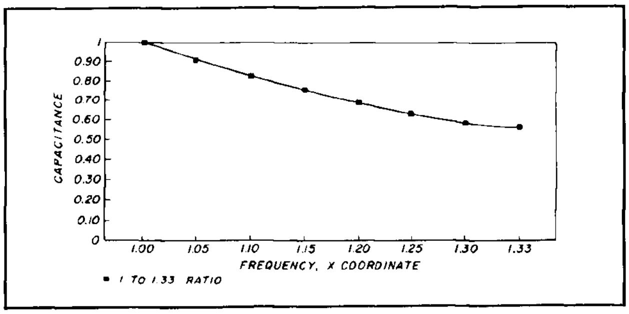
You want a capacitance equation that produces linear tuning. For a parallel LC-tuned circuit the resonant frequency is given by:

$$f = \frac{1}{2\pi\sqrt{LC}} \quad \textbf{(8)}$$

Solving for C: $C = \frac{1}{4\pi^2 L f^2}$ **(9)**

If the frequency increases linearly, the capacitance must decrease as the reciprocal of the square of the frequency. Suppose you want to cover the 3 to 4-MHz range. This is a $1{:}1.\overline{333}$ frequency ratio. **Figure 4** shows how the capacitance must change across the frequency range. Note the shape of the curve; the correct one will be the curve corresponding to **Figure 2** for linear tuning over a $1{:}1.\overline{333}$ ratio.

FIGURE 4

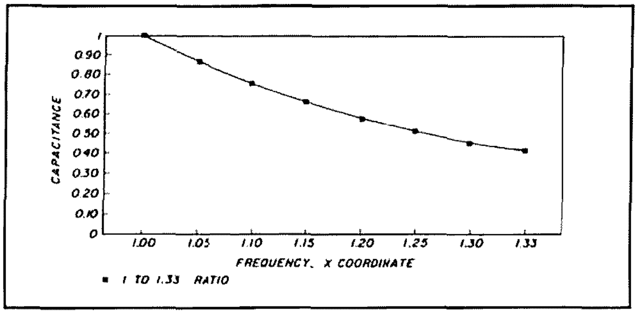


Required tuning capacitance as a function of frequency.

The capacitance curve will be the same for any $1{:}1.\overline{333}$ tuning ratio. The exact range will be set by inductance L, whether it's 3 to 4 or 6 to 8 MHz. However, another tuning ratio will require a different **Figure 4** curve.

This means that you can only build a linear frequency tuning capacitor for one frequency ratio. These types of capacitors are specified by their minimum and maximum capacitances and frequency ratios. But you may require a certain fixed capacitor in parallel with the tuning capacitor to achieve the correct curve from **Figure 4**. It's possible to design a linear frequency capacitor to allow for stray or feedback capacitance from the oscillator circuit.

FIGURE 5



Equation 10* data shows shape of capacitor plate to give capacitance curve of *Figure 4.

To determine the plate shape needed to give the capacitance curve of Figure 4, take the derivative of Equation 9:

$$\frac{dC}{dF} = \frac{-1}{2\pi^2 L f^3} \qquad (10)$$

The top edge of the capacitor must vary as the reciprocal of the cube of the frequency (ignore the negative sign).

This curve is plotted in Figure 5 for the $1{:}1.\overline{333}$ frequency ratio. The inductance is used to set the exact frequency range once again. The analysis gets more complex if you're removing a final amount of capacitance to allow for circuit capacitance. It can be done, but I won't discuss that process in this article.

You could trace Figure 5, place the tracing on a piece of sheet metal, cut out one or more plates, and use them to construct a linear frequency tuning capacitor with horizontal motion. I haven't tried this yet; maybe one of you will. What about a rotary capacitor? The mathematics are analogous using polar coordinates. I haven't included it here, but the principles are the same. Like the linear frequency tuning capacitor, a rotary linear frequency capacitor is good for only one frequency ratio. That ratio can be scaled to any range by inductance selection, and the variable capacitor may allow for a fixed external capacitance in the oscillator circuit.

Now that the background is out of the way, I'll describe how to build an oscillator using a precision variable capacitor available at little or no cost.

Tuning capacitor

The 35 to 150-pF main tuning capacitor from ARC 5 WWII command-set transmitters is one of the finest variable capacitors available to Amateurs. It is still listed in Fair Radio Sales catalogs.* You can buy the capacitor alone or purchase the whole transmitter (not all of them come complete). The same capacitor seems to have been used for the 2.1 to 3, 3 to 4, 4 to 5.3, 5.3 to 7, and 7 to 9.1-MHz models. Actually, the transmitters contain two similar capacitors. The only difference between them is that the front one, used for tuning the final amplifier, has a dial drive attached. Many old-timers may still have these caps in their junkboxes. The capacitor is shown in Photo A.

*Fair Radio Sales Company, PO Box 1105, Lima, Ohio 45802

A worm drive with an anti-backlash gear moves the adjustable plates. Exactly 96 turns of the shaft take the capacitor through 360 degrees. Of course, you can only use a maximum of 180 degrees; I recommend slightly less to avoid errors at the beginning and end.

In capacitors with the dial drives, the worm drive moves the plates while another set of anti-backlash gears rotates the dial. Exactly 99 turns of the shaft move the dial through 720 degrees, or two revolutions. Because of this difference, you shouldn't rotate the capacitor 360 degrees. The dial will be off by three turns of the shaft after it revolves twice.

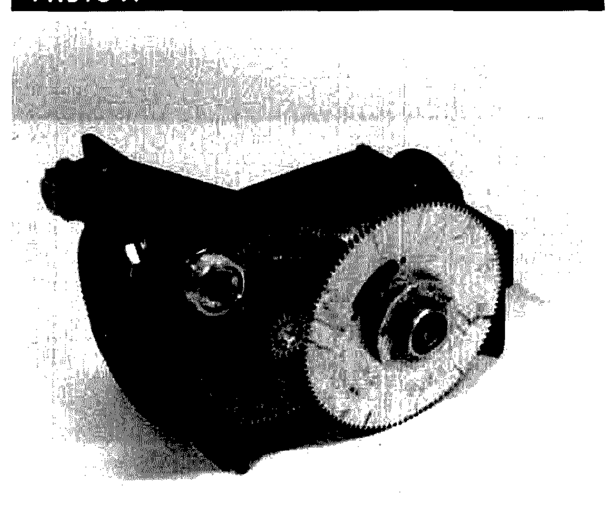
An examination of the dials shows that they're not linear. For example, 3.7 turns of the main shaft move the dial from 4 to 4.1 MHz, but 3.2 turns are needed to move it from 5.2 to 5.3 MHz. Photo B shows two representative dials.

Because these capacitors have excellent gear drives, I decided to determine just how far off they would be for typical Amateur tuning ranges. After all, 7.0 to 9.1 MHz is a pretty wide range for Amateur use. Even a capacitor with linear capacitance plates can give a fairly good approximation of linear frequency over a small frequency ratio. The plates on this capacitor are closer to linear frequency; there is a smaller radius at the high-frequency (minimum capacitance) end than at the low-frequency one.

Frequency error

I mounted a circular protractor on the dial drive in place of the surplus dial and took frequency measurements every 10 degrees from 0 to 300. The protractor was placed at the point

PHOTO A



Tuning capacitor.

PHOTO B

Two representative dials.

where the plates were fully meshed (330 degrees). I used a homebrew frequency counter to take readings to the nearest 5 kHz. The raw data is shown in **Table 1**.

The oscillator circuit is shown in **Figure 6**. I chose values and adjusted the inductance for the feedback capacitors, C_X, and coupling capacitor to cover a 4 to 5.3-MHz range.

The plot of frequency versus dial rotation shown in **Figure 7** looks good, but this kind of plot can be misleading. Very large, inherent errors of greater than 10 kHz are present. There are measurement errors based on how accurately the dial is positioned in reference to the 10-degree marker on the protractor scale. There's also a ±2.5-kHz error; I recorded the frequency only to the nearest 5 kHz when I could have taken it to the nearest Hz with this counter.

I used a curve-fit technique to minimize or average out the measurement errors. Drawing a straight line (mathematically) through the data points minimizes the frequency error between the raw data points and the straight line. This is referred to as linear least-square curve fitting because the sum of the squares of the errors is minimized.

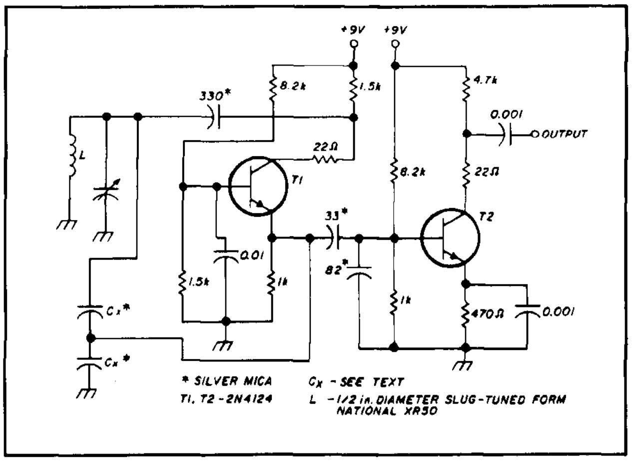
Using a straight line like this is the best way to match a linear dial over the frequency ratio selected. You can adjust the oscillator circuit's "fixed" capacitor and inductor to achieve the same deviation from a linear dial that you'd get from the

TABLE 1

Test data taken to determine dial position and frequency of a surplus WWII command-set capacitor.

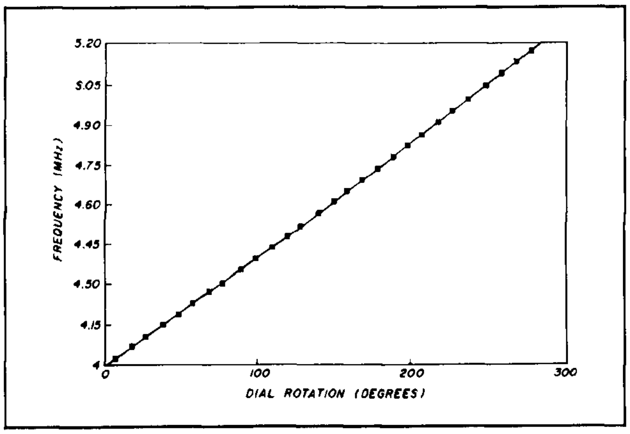
Dial Position (degrees)	Frequency (MHz)
0	4.0
10	4.03
20	4.07
30	4.11
40	4.15
50	4.19
60	4.23
70	4.27
80	4.31
90	4.355
100	4.40
110	4.44
120	4.48
130	4.52
140	4.565
150	4.61
160	4.65
170	4.69
180	4.74
190	4.78
200	4.825
210	4.87
220	4.91
230	4.96
240	5.0
250	5.05
260	5.09
270	5.14
280	5.18
290	5.23
300	5.27

FIGURE 6



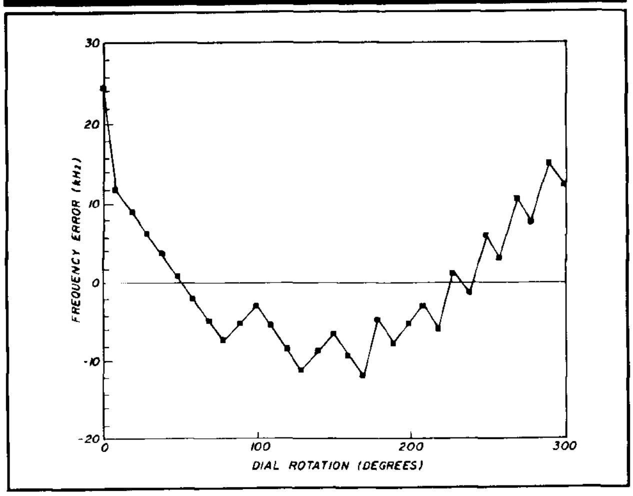
Oscillator circuit used for frequency-error measurements.

FIGURE 7



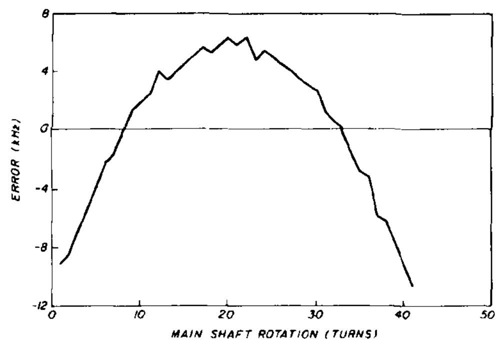
Plot of frequency versus dial rotation looks linear but can be misleading. Measurement errors are minimized using a curve-fit technique as in *Figure 10*.

FIGURE 8



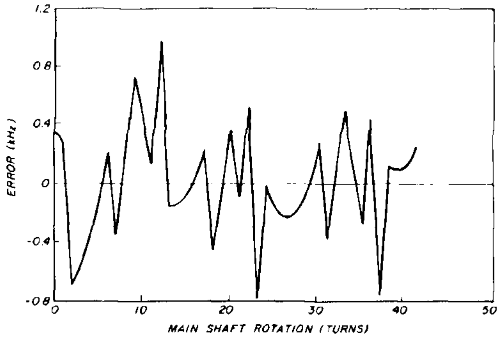
Plot of frequency error versus dial rotation. A least-squares curve fit minimizes errors.

FIGURE 9



Error curve for a straight-line fit to the raw data of *Table 2*.

FIGURE 10



Deviation from a parabola. Data shows less than 1-kHz error and random scatter indicates a good fit.

deviations between the measured data and the best straight-line fit. **Figure 8** shows a plot of the deviations for the 4 to 5.3-MHz range. It's easier to see how far off a linear dial will be with the plot in **Figure 8** than it is with the one in **Figure 7**.

At the low end of the dial the error starts off positive; that is, the actual frequency will be about 10 kHz higher than indicated on the dial. In the center the error is 10 kHz negative, and at the high-frequency end it's 10 kHz positive again. At two points the frequency will match the dial reading exactly. The parabolic nature of the error curve is rather ragged in appearance, undoubtedly due to the measurement errors indicated earlier.

Numerous computer programs are available for curve-fit calculations. Some sophisticated calculators have this feature. You can do the calculations yourself using a simple calculator and the formulas from a math or statistics textbook. I recommend using a computer; even the smallest personal computer can handle the calculations. Some programs can also calculate higher order curves, in addition to straight-line fits.

I smoothed the ragged appearance of the error curve in **Figure 8** in two ways. For actual frequency measurements, I took more care in positioning the dial directly under a cross hair while recording the frequency to the nearest 1-kHz reading. In addition, I made a second-order curve fit to the raw data. Because the error curve seems to have a parabolic shape, a second-order curve (parabola) fits the raw data quite well.

Figure 9 shows the error curve for a straight-line fit to the raw data of **Table 2**. I took frequency readings to the nearest kilohertz for each single turn of the main shaft. I made 49 turns and selected the 42 center readings to eliminate errors at the ends of the capacitor range. My readings covered about 300 degrees of the main dial, including the 3746 to 4083-kHz range. **Figure 10** shows the plot of raw data versus a square fit (parabola), along with the resulting error. There's a less than 1-kHz error; the random scatter indicates the fit is as good as possible and is probably limited by measurement errors.

Using the smoothed raw data (parabola), I can find the best straight-line fit to determine the error from a linear dial. **Figure 11** shows the result of my calculation. Now compare **Figure 11** with **Figure 10** and you'll see that raggedness

TABLE 2

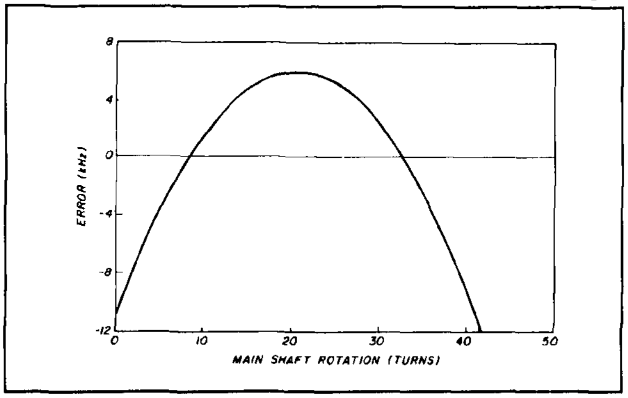
Frequency readings between 3746 and 4083 kHz taken to produce error as a function of capacitor shaft rotation in *Figure 10*.

Turning shaft (turns)	Frequency (kHz)	Tuning shaft (turns)	Frequency (kHz)
0	3746	26	3950
1	3750	27	3958
2	3756	28	3965
3	3763	29	3972
4	3772	30	3979
5	3780	31	3986
6	3789	32	3993
7	3798	33	4000
8	3807	34	4006
9	3816	35	4013
10	3824	36	4020
11	3833	37	4026
12	3842	38	4032
13	3850	39	4039
14	3858	40	4044
15	3867	41	4051
16	3874	42	4057
17	3882	43	4063
18	3890	44	4069
19	3898	45	4074
20	3906	46	4078
21	3913	47	4083
22	3921	48	4085
23	3929	49	4083
24	3936		
25	3944		

introduced by the measurement error has been removed; however, the basic error remains. This basic error results from the incorrect shape of the capacitor plates used over the particular frequency ratio in **Table 2**.

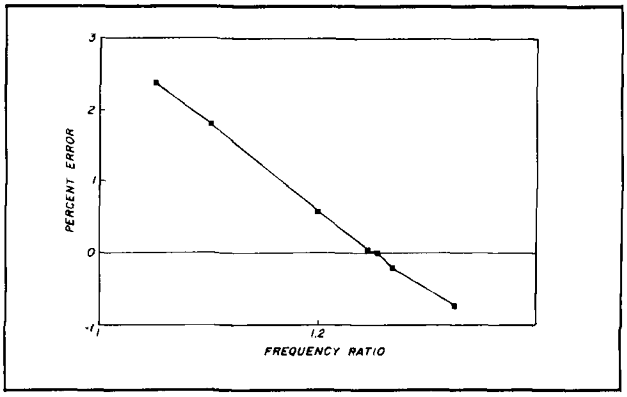
How does the error for this type of precision-tuning capacitor change with the frequency ratio covered? True straight-line frequency capacitors are designed for only *one* frequency ratio. Does this capacitor have a ratio where the error will be at its lowest?

FIGURE 11



Smoothed raw data (parabola) is used to find the best straight-line fit to determine the error from a linear dial.

FIGURE 12



Percent error for a WWII tuning capacitor. Tuning range was about 200 to 1300 kHz at center dial frequency of 4.6 MHz.

More measurements

I tried a variety of tuning ratios using the procedure just described. I selected fixed capacitors from 50 to 500 pF and investigated frequency ratios from less than 1.1:1 to over 1.3:1. My tuning range was about 200 kHz to over 1300 kHz at the center dial frequency of 4.6 MHz. I calculated the percentage error by dividing the error at the dial center by the tuning range. As I mentioned previously, you can make the error small for almost any capacitor by restricting the tuning range. Calculating the percentage error, however, highlights the true error of the capacitor.

The results are shown in **Figure 12**. Note that the error is positive at the dial center for ratios below 1.25:1 and negative for ratios above. This reverses the parabolas of **Figures 8** and **9**. As it turns out, the best ratio is 1.25:1. The error here seems to be very close to zero. In fact it's less than 0.1 percent.

Practical use

With errors this small, you can construct high-performance linear tuning dials. For example, a 500-kHz range can be covered with less than 0.5-kHz error. You could also use the circular protractor degree markings to cover the 300 kHz from 1.2 to 1.5 MHz.

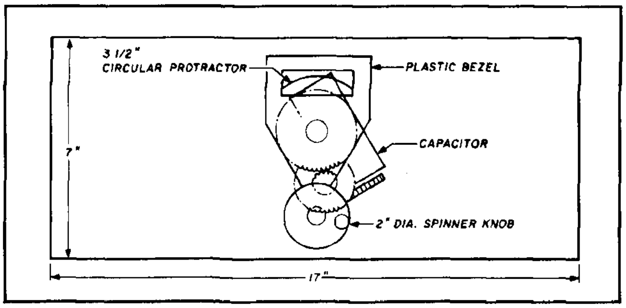
Transceiver builders are interested in the 4.8 to 6-MHz range. By using just the top 5.5 to 6 MHz, you can build a nice master VFO. It's also possible to make a remote VFO for use with the popular commercial transceivers. Precision linear dials are practical for Amateur measuring instruments like signal generators and R-X bridges. I'm sure you can find many more applications.

I have one suggestion that should make your transceiver front panel layout more attractive. Mount the capacitor at an angle so the main shaft is aligned directly below the center of the dial as shown in **Figure 13**.

Conclusion

The theory of linear tuning capacitors led me to explore the use of surplus capacitors in Amateur applications. I've given construction details for practical precision dials. Remember that it's important to select a 1.25:1 frequency ratio for 300 degrees rotation of the main dial.

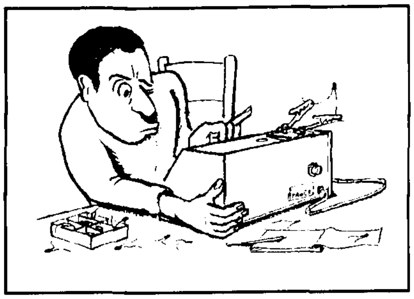
FIGURE 13



Transceiver application.

I still don't know why the original dials from WWII gear are nonlinear. They appear to use a 1.32:1 frequency ratio. Was the capacitor designed for one ratio, but used with another? Was it a trial-and-error procedure that was put aside too soon? I'd like to hear from anyone who knows what happened.

Practically Speaking



Joe Carr, K4IPV

PART 1

HIGH-FREQUENCY DIPOLE ANTENNAS

Last month I discussed the basic ingredients of the dipole antenna. This antenna has acquired an undeservedly poor reputation in an era of multiband beams and other costly antennas. When installed correctly (which is easy to do), the dipole turns in a credible performance. In fact, some poorly constructed (or designed) commercial three-element beam antennas perform only as well as a dipole at the same height. The dipole antenna performs well for the money, time, and brainpower invested. This month I'll take a second look at this antenna and discuss how you might go about tuning one. I'll also describe dipole variants like the broadbanded and loaded dipoles.

Tuning the dipole antenna

There are two issues to address when tuning an antenna (any antenna, not just the dipole): *resonance* and *impedance matching*. Although they are frequently treated in the literature as the same issue, they are not. In this article I'll deal primarily with the process of tuning the antenna to resonance. Not all antennas are resonant, but the dipole is.

There's a lot of misinformation on antenna tuning. Perhaps much of what is believed is a result of using VSWR as the indicator of both resonance and impedance matching. Many people honestly (but erroneously) believe that the VSWR can be "tuned out" by adjusting the feedline length. That myth probably derives from the fact that voltage or current-sensing instruments are used for VSWR measurement, and these are affected by transmission line length. But the problem lies in the instruments; it's not a fact of radio physics. Another factor which leads to confusion is that varying the line length may provide an impedance transformation that matches the antenna to the transmitter, but doesn't address the point that the antenna is off resonance and therefore less efficient.

There's only one proper way to tune a dipole antenna — *adjust the length of the antenna elements.* You don't adjust the transmission line. As I mentioned when discussing construction methods last month, you leave the electrical connections at the center insulator unsoldered so you can make these adjustments.

The minimum point in the VSWR curve is the resonance indicator. **Figure 1** shows a graph of VSWR versus frequency for several different cases. Curve A represents a disaster — a high VSWR across the band. The actual VSWR value may be anything from about 3.5:1 to 10:1 (or thereabouts), but the cause is the same. The antenna is either open or shorted, or is so far off resonance that it appears open or shorted to the VSWR meter.

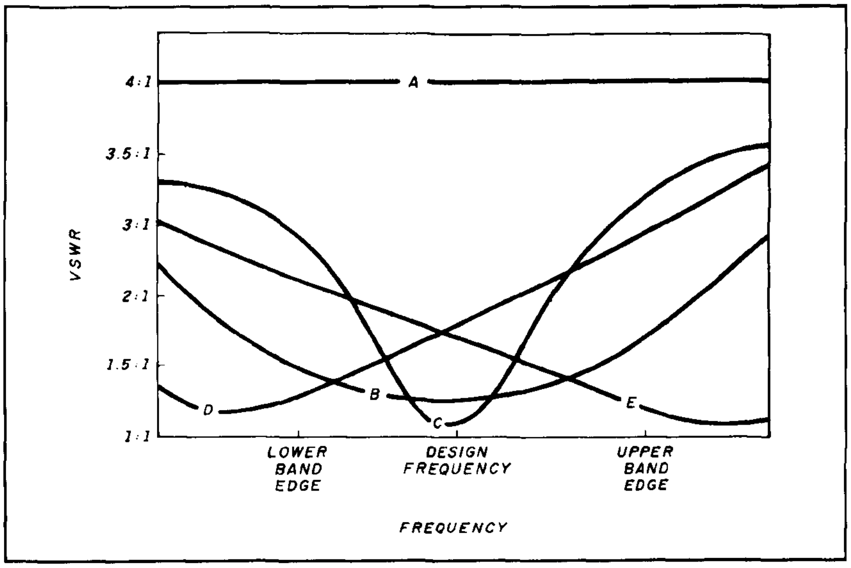
Curves B and C represent antennas that are resonant within the band of interest. Curve B represents a broadbanded antenna that's relatively flat across the band, and doesn't exhibit excessive VSWR until the frequency is outside the band. Curve C is also resonant within the band, but this antenna has a lot higher Q than curve B. In the simplest sense the broadbanded antenna is best, but that statement is true only if broadness is not purchased at the expense of efficiency. Resistive losses tend to broaden the antenna frequency response but also reduce its effectiveness. The antenna is effectively "broadbanded," as seen by the transmitter, by the addition of the equivalent of a power-absorbing resistor at the feedpoint. Again, it's undesirable if this broadbandedness is purchased at the cost of increased loss.

Curves D and E in **Figure 1** are resonant outside the band of interest. The D curve is resonant at a frequency on the low side of the band, making that dipole too long. In this case you need to shorten the antenna to raise the resonant point inside the band. Curve E represents an antenna that's resonant outside the upper limit of the band; this antenna is too short and must be lengthened. Because the antenna is frequently too short, cut the elements longer than necessary at first.

How much you cut depends on two factors: how far the resonant point is from the desired frequency, and which band you're working on. The second requirement results from the fact that the "frequency per unit" length varies from one band to another. Let's look at an example of how to calculate this figure. The procedure is simple:

- Calculate the length required for the upper end of of the band.
- Calculate the length required for the lower end of the band.
- Calculate the difference in lengths for upper and lower ends of the band.
- Calculate the width of the band in kilohertz by subtracting the difference between the upper frequency limit and the lower frequency limit.

FIGURE 1



VSWR versus frequency for several cases.

- Divide the length difference by the frequency difference; the result is in kilohertz per unit length.

Example

Calculate the frequency change per unit of length for 80 and 15 meters.

Solution:

For 80 meters (3.5 to 4.0 MHz):

$L_{ft} = 468/4\ MHz = 117\ feet$

$L_{ft} = 468/3.5\ MHz = 133.7\ feet$

Difference in length: $133.7\ feet - 117\ feet = 16.7\ feet$.

Frequency difference: $4000\ kHz - 3500\ kHz = 500\ kHz$.

Calculate frequency/unit length: $500\ kHz/16.7\ feet = 30\ kHz/foot$.

For 15 meters (21.0 to 21.45 MHz):

$L_{ft} = 468/21.45 = 21.82\ feet$

$L_{ft} = 468/21 = 22.29\ feet$

Difference in length: $22.29 feet - 21.82\ feet = 0.47\ feet$.

Convert to inches: $0.47\ feet \times 12\ inches/foot = 5.64\ inches$.

Frequency difference: $21{,}450\ kHz - 21{,}000\ kHz = 450\ kHz$.

Calculate frequency/unit length: $450\ kHz/5.64\ inches = 80\ kHz/inch$.

The frequency change per foot at 80 meters is small, but even small changes can result in very large frequency shifts at 15 meters. You can calculate approximately how much to add or subtract from an antenna under construction using this kind of calculation. If, for example, you design an antenna for the so-called "international net frequency" on 15 meters (21,390 kHz), but find the actual resonant point is 21,150 kHz, then the frequency shift required is 21,390 − 21,150, or 240 kHz. To determine how much to add or subtract (as a first guess):

The factor for 15 meters is 80 kHz/inch, which is the same as saying 1 inch/80 kHz.

The required frequency shift is 240 kHz.

Therefore:

$$Length\ change = 240\ kHz\ \frac{1\ inch}{80\ kHz}$$

$$Length\ change = 3\ inches$$

Each side of the antenna must be adjusted by half the length calculated above, or 1.5 inches. Because the first resonant frequency is less than the desired one, you should shorten the length by 1.5 inches. Once the length is correct (as proven by the VSWR curve), solder the connections at the center insulator to make them permanent, and hoist the antenna back to operating level.

You can see the difference between resonance and impedance matching in the value of the VSWR minimum. While the minimum indicates the resonant point, the value of that minimum is a measure of the relationship between the feedpoint impedance of the antenna and the characteristic impedance of the transmission line. Last month you learned that:

$Z_o > R_r$:

$$VSWR = Z_o/R_r \qquad (1)$$

$Z_o < R_r$:

$$VSWR = R_r/Z_o \qquad (2)$$

Where:

Z_o is the coaxial cable characteristic impedance.

R_r is the radiation resistance of the antenna.

Although knowing the VSWR won't tell you which situation is true, you'll know that there's a high probability that one of them is. Experiment to find which is the case. Of course, if the VSWR is less than about 1.5:1 or 2:1 then forget about it; the improvement isn't generally worth the expense and cost. When the transmission line is coupled to a transmitter that's equipped with a tunable output network (most tube-type transmitters or final amplifiers), it can accommodate a relatively wide range of reflected antenna impedances. But modern solid-state final amplifiers tend to be a little more picky about the load impedance. For these transmitters a coax-to-coax antenna-tuning unit (ATU) is needed.

Other dipoles

So far I've discussed classic dipoles with half-wavelength single conductor radiator elements connected to a coaxial transmission line. This type of antenna is most often installed horizontally a half wavelength above the ground (or wherever convenient if that's impossible). Next I'll take a look at other forms of dipoles. Some of these are equal in every way to the horizontal dipole; others are basically compensation antennas used when a proper dipole isn't practical.

Inverted-V dipole

The inverted-V dipole is a half-wavelength antenna fed in the center like a dipole. By definition, the inverted-V is merely a variation on the dipole theme. In this antenna (**Figure 2**) the center is elevated as high as possible above ground, but the ends droop very close to the surface. Angle

"a" can be almost any convenient angle greater than 90 degrees. Most inverted-V antennas use an angle of about 120 degrees. This antenna provides a compromise when a dipole can't be used. Many operators believe it's a better performer on 40 and 80 meters in cases where the dipole can't be mounted at a half wavelength (64 feet or so).

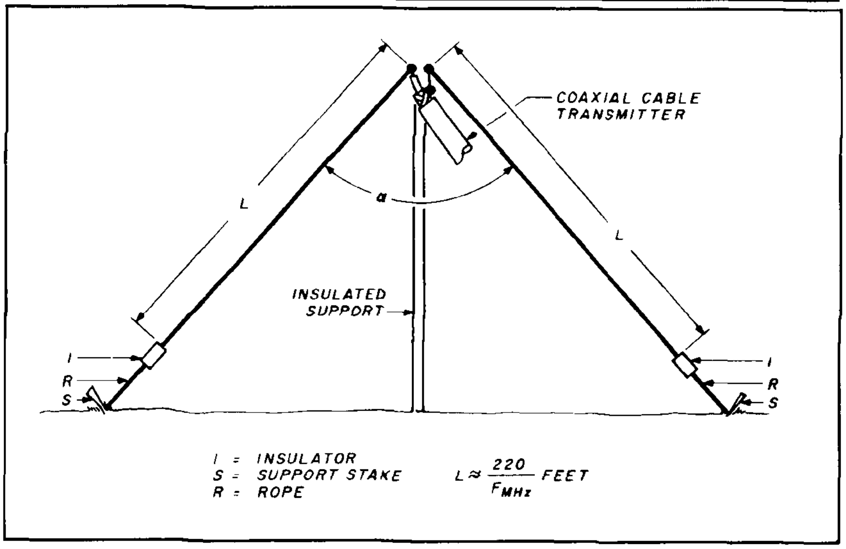
Sloping the antenna elements down from the horizontal to an angle (**Figure 2**) effectively lowers the resonant frequency. This means the antenna will need to be shorter than a dipole for any given frequency. There's no absolutely rigid equation for calculating the overall length of the antenna elements. Although the concept of "absolute" length doesn't hold for regular dipoles close to the ground, it's even less viable for the inverted-V. There is, however, a rule of thumb you can use for a starting point — make the antenna about 5 percent shorter than a dipole for the same frequency. Try cutting the antenna to the length required for a regular dipole on the same frequency and trim from there, using the tuning procedure.

$$L = \frac{468}{F_{MHz}} \textit{feet} \qquad \textbf{(3)}$$

After determining the approximate length, find the actual length with the same cut-and-try method used to tune the dipole in the previous section.

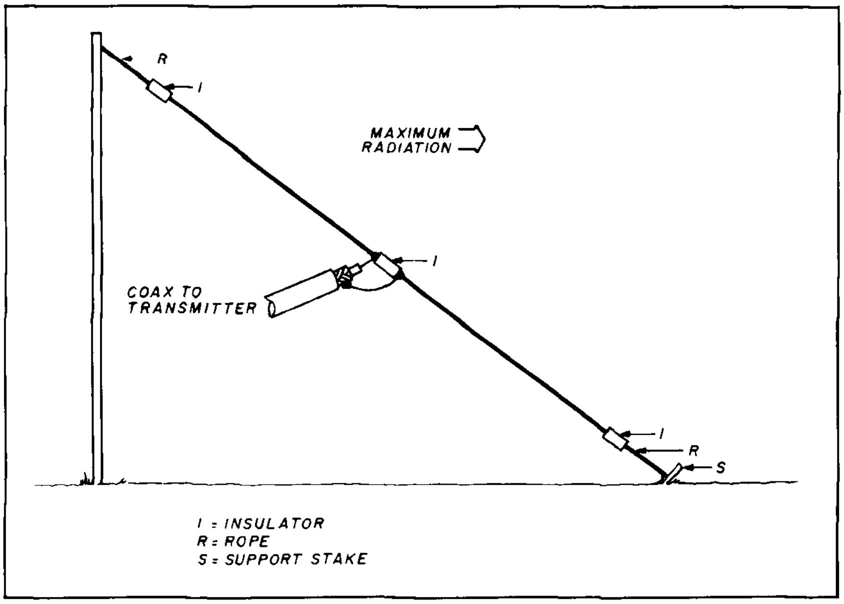
Sloping the elements changes the feedpoint impedance of the antenna and narrows its bandwidth. You'll need to make some adjustments as a result. You might want to use an impedance-matching scheme at the feedpoint, or an antenna tuner at the transmitter.

FIGURE 2



Inverted-V dipole antenna.

FIGURE 3



Sloper dipole (also called "slipole").

Sloping dipole ("sloper" or "slipole")

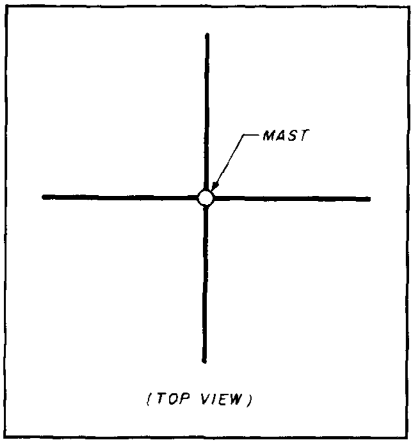
The sloping dipole in **Figure 3** is popular with operators who need a low angle of radiation but don't have a large area for their antenna installation. Various texts call this antenna the sloper or the slipole. I use the term slipole to distinguish this antenna from a sloping vertical. But whatever you call it, it's a half-wavelength dipole with one end at the top of a support and the other end close to ground, fed in the center by coaxial cable.

Some operators like to hang four sloping dipoles from the same mast pointing in different directions (**Figure 4**). A single four-position coaxial cable switch lets you switch a directional beam on different headings that favor various locations.

Broadbanded dipoles

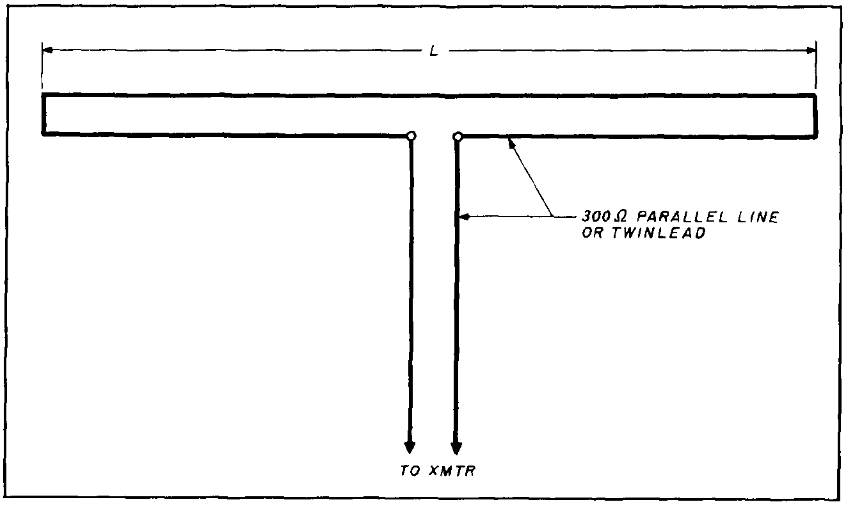
It is rarely discussed that the length/diameter ratio of the conductor used for the antenna element is a factor in determining antenna bandwidth. In general, a large cross-sectional area makes the antenna more broadbanded. In some cases, using aluminum tubing instead of copper wire for the antenna radiator is advisable. Tubing is a viable solution on the higher frequency bands. Aluminum tubing is inexpensive, lightweight, and easily worked with common tools. You can make a rotatable directional dipole with ordinary aluminum tubing. But as

FIGURE 4



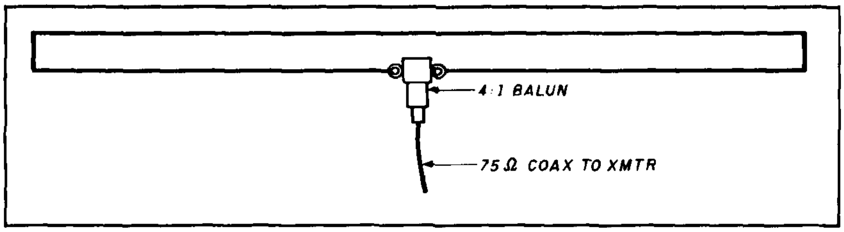
Several slopers supported from a common mast give directional characteristics.

FIGURE 5A



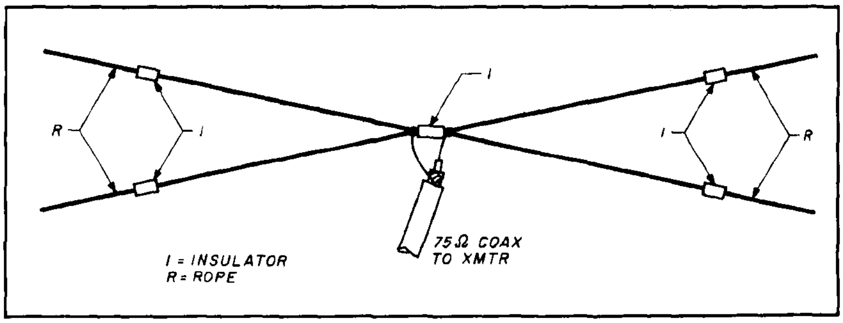
Folded dipole fed with twin lead.

FIGURE 5B



Folded dipole fed with coax and a 4:1 BALUN.

FIGURE 6



Broadbanded "bowtie" dipole.

the frequency decreases, the weight becomes greater. This is because the tubing is longer and must be of greater diameter for structural strength.

Aluminum tubing is impractical on 80 meters and nearly impractical on 40. Yet it's at 80 meters that you find a significant problem (especially with certain older transmitters). The band is 500 kHz wide, and older transmitters often lack the tuning range for the entire band. Three basic solutions to the problem of wide bandwidth dipole antennas are: the *folded dipole*, the *bowtie dipole*, and the *cage dipole*.

Figure 5A shows the folded dipole antenna. It's basically two half-wavelength conductors shorted together at the ends and fed in the middle of one of them. The folded dipole is usually constructed from 300-ohm television antenna twin-lead transmission line. Because the feedpoint impedance is nearly 300 ohms, you can use the same type of twin lead for the transmission line. The folded dipole exhibits excellent wide bandwidth properties, especially on the lower bands.

For a folded dipole the transmitter has to match the 300-ohm balanced transmission line, which is a disadvantage. Unfortunately, most modern radio transmitters are designed to feed coaxial cable transmission line. Although you can place an antenna tuner at the transmitter end of the feedline, it's also possible to use a 4:1 balun transformer at the feedpoint (**Figure 5B**). This arrangement makes the folded dipole a reasonable match to 52 or 75-ohm coaxial cable transmission line.

Another method for broadbanding the dipole is to use two identical dipoles fed from the same transmission line arranged to form a "bowtie," as shown in **Figure 6**. Using two identical dipole elements on each side of the transmission line increases the conductor cross-sectional area, so the antenna has a slightly improved length/diameter ratio.

The bowtie dipole was popular in the 1930s and '40s; it was the basis for the earliest television receiver antennas. (TV signals are 3 to 5 MHz wide and require a broadbanded antenna.) This antenna was also popular during the 1950s as the so-called "Wonder Bar" antenna for 10 meters. Some are still in use, but the antenna's

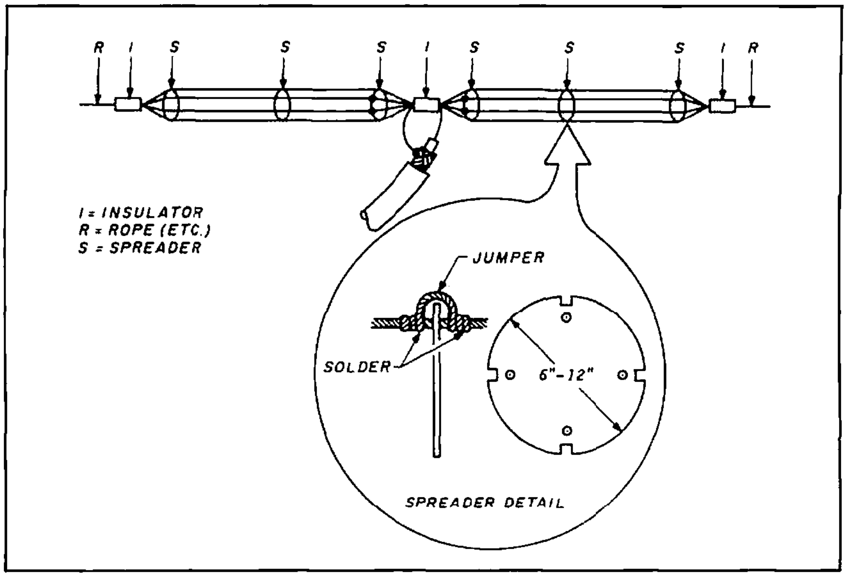


FIGURE 7

I = INSULATOR
R = ROPE (ETC.)
S = SPREADER

Cage dipole.

popularity has faded. The ends are spread to approximately 11 percent of the total length.

The cage dipole (**Figure 7**) is similar to the bowtie in concept, if not construction. Again, the idea is to connect several parallel dipoles extending from the same transmission line in an effort to increase the apparent cross-sectional area. But with the cage dipole, spreader disk insulators keep the wires separated. The insulators can be built from Plexiglas™, lucite, or ceramic. They may also be made of materials like wood that's properly treated with varnish, polyurethene, or any other material that prevents waterlogging. The spreader disks are held in place with wire jumpers (see inset to **Figure 7**) soldered to the main element wires.

Some bowtie and cage dipole builders make the elements slightly different lengths. This "stagger tuning" method forces one dipole to favor the upper end of the band and the other to favor the lower end. The overall result is a slightly flatter frequency response characteristic across the entire band. On the cage dipole, with four half-wavelength elements, it should be possible to overlap even narrower sections of the band in order to create an even flatter characteristic.

Shortened dipoles

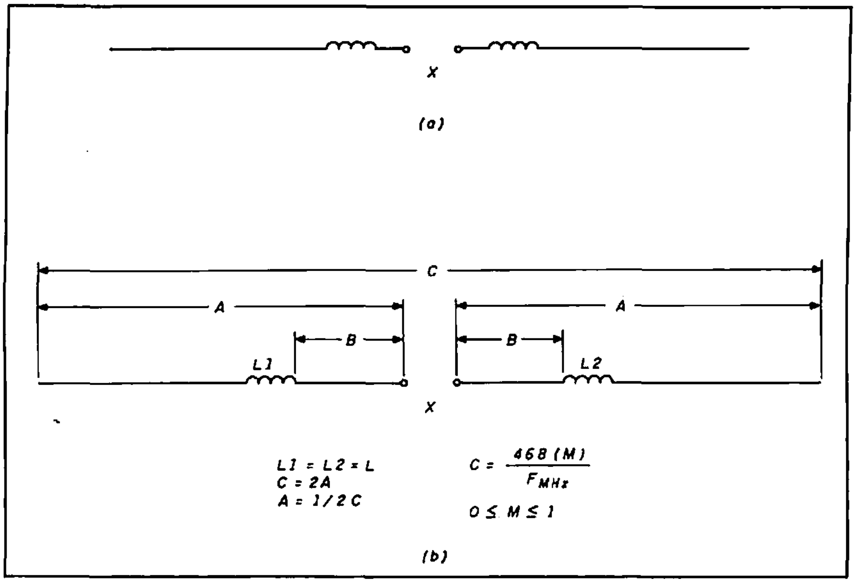
The half-wavelength dipole is too long for some applications — espe-

TABLE 1

Approximate inductance reactances as a function of the percentage of half wavelength represented by the shortened radiator.

Percent of half wavelength	Coils at feedpoint (ohms)	Coils at middle of radiators (ohms)
20	1800	2800
30	950	1800
40	700	1300
50	500	950
60	360	700
70	260	500
80	160	320
90	75	160
95	38	80
98	15	30

FIGURE 8



Coil-loaded dipole: a) coils at feedpoint; b) coils at 50-percent point.

cially where real estate is at a premium. Many operators solve this problem by using a coil-loaded shortened dipole like the one shown in **Figure 8**. A shortened dipole (one which is less than half a wavelength) is capacitive, so it must have an in-line inductance to compensate for the inherent capacitive reactance. There's no reason why the loading coil can't be put at any point along the radiator, but in **Figures 8A** and **8B** they are placed at 0 and 50 percent of the element length, respectively. This makes coil inductance calculations easier, and also represents the most common practice.

Table 1 shows approximate inductive reactances as a function of the percentage of half wavelength represented by the shortened radiator. It's likely that the percentage figure will be imposed on you by the situation, but the general rule is to pick the largest figure consistent with the available space. For example, suppose you have about 40 feet available for a 40-meter antenna that normally needs about 65 feet for a half wavelength. Because 39 feet is 60 percent of 65 feet, you can use this value as the design point for your antenna. In **Table 1** you'll see that a 60-percent antenna with the loading coils at the midpoint of each radiator element wants to see an inductive reactance of 700 ohms. Rearrange the standard inductive reactance equation (X_L = 6.28 FL) to the form:

$$L_{\mu H} = \frac{X_L \times 10^6}{6.28\ F}$$

Where:

$L_{\mu H}$ is the required inductance in microhenries.
F is the frequency in hertz (Hz).
X_L is the inductive reactance calculated from Table 1.

Example

Calculate the inductance required for a 60-percent antenna operating on 7.25 MHz. The table requires a reactance of 700 ohms for a loaded dipole with the coils in the center of each element (**Figure 8B**).

Solution:

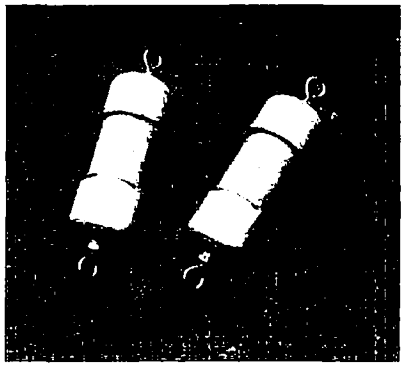
$$L\mu H = X_L \times 10^6/6.28\ F$$
$$L\mu H = (700)(10^6)/(6.28)(7{,}250{,}000)$$
$$L\mu H = 7 \times 10^8/4.6 \times 10^7 = 15.4\ \mu H$$

The calculated inductance is approximate and may have to be altered by cut-and-try methods.

The loaded dipole antenna is very sharply tuned. Because of this, you must either confine operation to one segment of the band or provide an antenna tuner to compensate for the sharpness of the bandwidth characteristic. However, efficiency drops markedly far from resonance, even with a transmission line tuner. The tuner overcomes the bad effects on the transmitter, but doesn't alter the basic problem. Only a variable inductor in the antenna will do that. (At least one commercial loaded dipole once used a motor-driven inductor at the center feedpoint.)

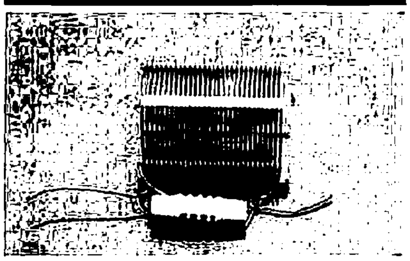
Photos A and **B** show two methods for making a coil-loaded dipole antenna. **Photo A** shows a pair of commercially available loading coils designed for this purpose. These coils are for 40 meters, but other models are also available. The inductor in **Photo B** is a section of B&W Miniductor connected to a standard end or center insulator. No structural stress is assumed by the coil; all forces are applied to the insulator.

PHOTO A



Commercial loading coils.

PHOTO B



Homebrew loading coil based on B&W Miniductor.

Conclusion

The dipole antenna is easy to design, easy to build, and well behaved enough that even novice builders can make it work successfully, and well. *Go for it!*

SIMPLE 75-OHM HARDLINE
TO 50-OHM MATCH

Put those CATV cable ends to use!

J. S. Gurske, K9EYY, 7240 Highway Y, Lodi, Wisconsin 53555

Have you ever measured the amount of RF power going into a coax feedline at, say, 2 meters and then measured the amount of RF coming out the other end? I did and I was amazed! I had about half the power at the far end of a 100-foot length of RG-8 cable. When I tried RG-58 coax, I had a power loss of about 75 percent. I didn't really believe my measurements, so I went to the coax tables. The tables list 100 feet of RG-8 coax (silver-plated center conductor with silver-plated double-shield outer braid) as having a loss at 150 MHz of about 2.5 dB. If you add a little more, because of connectors or standing wave ratio, you can easily approach 3 dB. That 3 dB reduces the signal power by one-half. In other words, if you have a 3-dB loss and 100 watts going into the coax, the 3 dB will cause a loss of 50 watts in the line. This means that the remaining power going to the antenna is 50 watts. Quite a price to pay! The RG-58 is even worse. The tables list its loss factor as 6 dB. Your 100 watts would be reduced by half and then by half again (or 75 percent), leaving 25 watts to appear at the other end of the cable. This, of course, assumes there are no other losses.

At about the time I was making these measurements and checking my data, the local cable operator gave me a "tag end" of 3/4" hardline. I'd heard that aluminum hardline was superior to RG-8 coax. The tables show a 1/2 dB loss at 150 MHz, over a 100-foot length.

I wanted to know how to match my 50-ohm equipment to the 75-ohm hardline. I remembered that a quarter-wave matching transformer was a possibility and looked up the formula for the impedance of the quarter-wave section. It was stated as follows:

$$Z_o = \sqrt{Z_1 \times Z_2} \qquad (1)$$

where: Z_0 = impedance of the line
Z_1 = the 50-ohm coax
Z_2 = the 75-ohm hardline

Solving for:

$$Z_o = \sqrt{50 \times 75} = \sqrt{3750} = 61.2 \text{ ohms} \qquad (2)$$

In other words, you'd need a coax with an impedance of 61.2 ohms to make a quarter-wave matching transformer.

At this point I shrugged my shoulders and was about to look for some other solution, because 61.2-ohm coax isn't what you'd call a standard item. Then I remembered that several hams in our area use copper pipe to make transformers. I had heard that they were easy to build for VHF and UHF ham communications. Using the *ARRL Handbook*, I found the formula for calculating the sizes of the inner and outer conductors for air-dielectric coax.

Calculations

The basic formula for calculating the inner diameter of the outer conductor and the outer diameter of the inner conductor is listed as follows:

$$Z_o = 138 \,Log\, D/d$$

where: Z_0 = impedance of the line
D = inner diameter of the outer conductor
d = outer diameter of the inner conductor

Since you already know that Z_0 is 61.2 ohms, you can rearrange the formula to solve for D, for example:

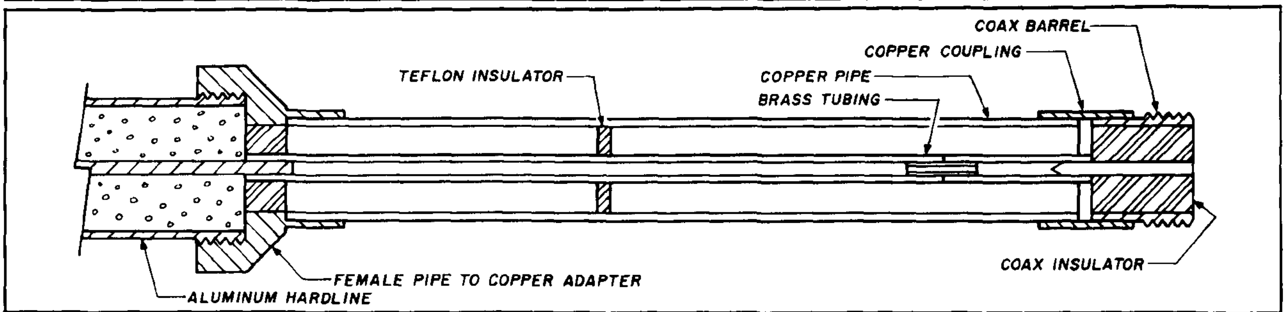
$$Z_o = 138 \,Log\, D/d$$
$$Z_o = 138\,(Log\, D) - (Log\, d)$$

$$D = 10^{\left(\frac{Z_o}{138}\right) + \log d} \qquad (3)$$

Substituting the appropriate numbers you find:

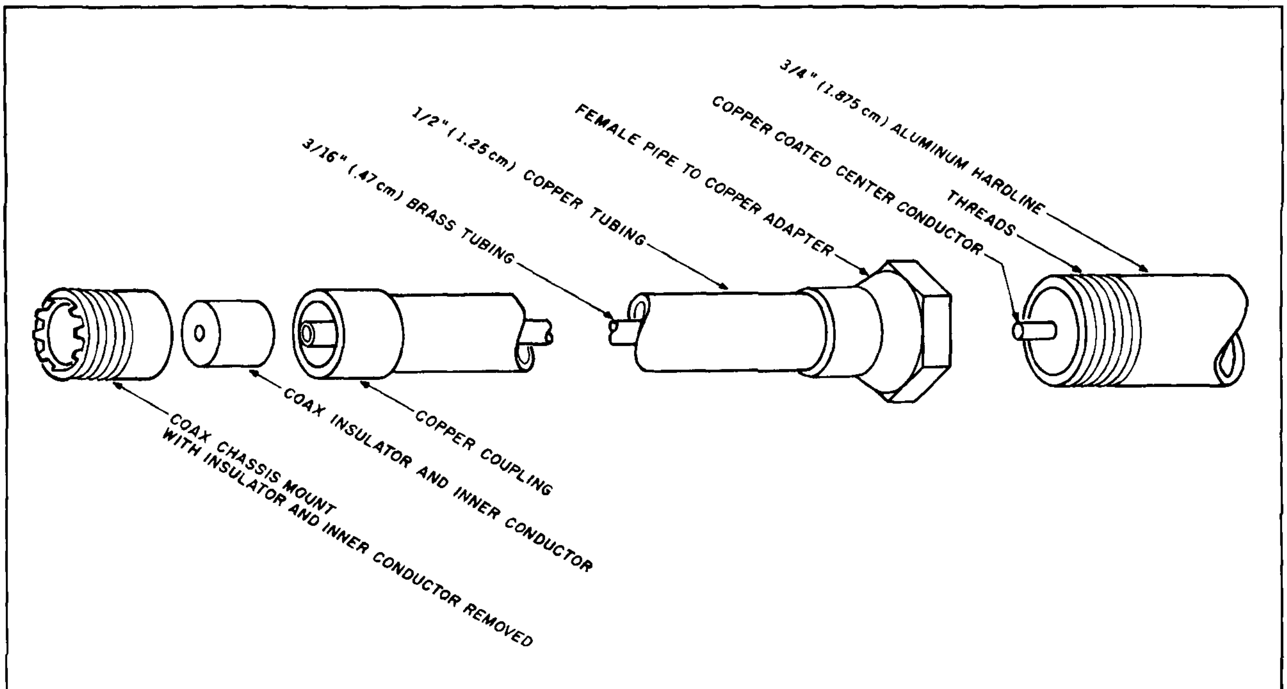
$$D = 10^{\left(\frac{61.2}{138}\right) + \log d} \qquad (4)$$

FIGURE 1



Detailed layout of the components used in the construction of a quarter-wave matching transformer for 75 to 50-ohm coax.

FIGURE 2



Expanded view of the quarter-wave matching transformer.

If you arbitrarily select 3/16" brass tubing (available at most hobby shops) for the inner conductor, you can solve for the larger conductor as follows:

$$D = 10^{\left(\frac{61.2}{138}\right) + (-0.7270)} = (0.4435) + (-0.7270) \quad \textbf{(5)}$$

$$D = 10^{(-0.2835)}$$

$D = 0.5205$ or just over 1/2".

This means that if you use 3/16" brass tubing for the inner conductor, you can use 1/2" copper pipe for the outer conductor. But what length should the transformer be? I wanted to use 147.225 MHz so I used the formula:

$$\frac{234}{freq.\ MHz} \text{ or } \frac{234}{147.225} = 1.589 \text{ feet or } 19 \text{ inches} \quad \textbf{(6)}$$

PARTS LIST

DESCRIPTION	QUANTITY
3/16-inch brass tubing	*4 pieces*
Small tubing to fit inside the above	*1 piece*
1/2-inch copper pipe 20 inches long	*2 pieces*
1/2-inch female pipe to 1/2-inch copper adapter	*2 pieces*
1/2-inch couplings	*2 pieces*
Teflon for bushings inside copper pipe	*2 pieces*
Noalox compound to prevent corrosion between the aluminum hardline and copper pipe (from electrical shops)	
Coaxial chassis mounts to be modified to fit into the copper couplings	*2 pieces*

Construction

To begin, measure the exact size of the *inner* diameter of the *outer* conductor you'll be using. Consult **Table 1** to find the corresponding brass center conductor. The brass tubing at the hobby store is sized so that the next smaller one slides snugly into the larger size. This is ideal for lengthening the tubing from the 12" standard lengths to whatever length you need. When you purchase the four pieces of brass tubing for the inner conductor, be sure to purchase one length of the next smaller size. Then you can sweat solder small lengths inside the larger brass tubes to make them longer.

The parts list covers most of the major items needed to build two quarter-wave matching transformers. You'll want to construct one matching section for each end of the hardline. (See **Figure** 1.) Here's the procedure I used to build the transformers.

- Trim both ends of the hardline back so that approximately 1/2" of the center conductor extends beyond the outer sheath. Carefully clean any plastic foam residue from the center conductor. The center conductor is copper plated. Be sure to leave the copper plating intact or you'll be unable to sweat solder the brass tubing to the center conductor.
- Run a 1/2" pipe-threading die onto each end of the hardline. The threads won't be very deep because the hardline is a little under size.
- Select a coax chassis mount and turn it down in a lathe (or file it) to remove the flange. This lets the coax barrel fit snugly inside the 1/2" copper coupling. Make two of these. I use N-type coax fittings, but UHF types work well also.
- Carefully remove the center conductor from the coax barrels. Some of these are held in with split washers; others are merely "press" fit, and some are swaged. If swaged, cut the swaging so the inner conductor and insulator slide out of the barrel (see **Figures 1, 2,** and **3**).
- Splice two pieces of the 3/16" brass tubing together using a 1" length of the smaller diameter brass tubing which slides inside this tubing. Sweat solder the joint; then fit the coax center conductor into one end of the 3/16" tubing. You might have to construct a bushing. Sweat solder this inner coax conductor to the brass tubing.
- Cut the other end of the brass tubing to the correct length. Measure from one end of the brass tube to the other. (Do not include the length of the coax center conductor in this measurement).
- Make a Teflon™ spacer to slide tightly over the tubing and inside the outer conductor (the 1/2" copper pipe). Sweat solder the brass tubing to the inner conductor of the hardline. See **Figures** 1 and 2.
- Temporarily thread the adapter onto the hardline. Cut a 1/2" copper pipe to approximately 20"; then slide one end into the adapter. Slide the copper coupling over the other end of the 1/2" copper pipe. Carefully measure the distance between the end of the brass tubing and the area in the coupling where the coax barrel will be placed. **Figure** 1 shows how the coax barrel should fit into the copper coupling. The brass tube should be up against the plastic insulation on the hardline on one end, and the coax inner insulator properly located in the coax barrel at the other end. Trim the copper pipe to exact length at this time. Double check to make sure everything fits together exactly as shown in **Figure** 1 and 2.
- Solder the copper pipe to the female pipe to copper adapter. Spread Noalox™ on the aluminum hardline threaded area and thread the adapter onto the hardline. Tighten the adapter on the hardline, being careful not to bend or otherwise distort the hardline. It's easy to strip the threads because they aren't deep. Be careful! Tape this connection to help keep moisture out of the joint.
- Assemble the copper coupling, coax insulator, center conductor, and coax barrel into final configuration. Sweat solder the copper coupling to the copper pipe and the coupling to the coax barrel.

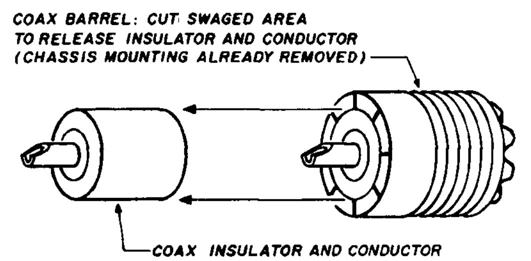
This completes the transformer. As I said before, you'll need one of these assemblies at each end of the 75-ohm hardline.

When I checked the power going into the cable and compared it with the power coming out the other end, I couldn't detect more than about 2 watts of loss over the 100-foot length. This was a far cry from my earlier measurements. I've used the system for over four years with no deterioration.

It was worth the small effort it took to build these quarter-wave matching sections. The 75-ohm hardline is cheap and the transformer makes it usable with 50-ohm devices. I hope you'll have the same good results. If I can be of any help, please send an SASE.

I want to thank my friend Rob Mayer who helped me rearrange the basic formulae when I got into trouble with logs.

FIGURE 3



Details for making the coaxial barrel to fit in the end of the 1/2-inch copper tubing.

TABLE 1

Some close approximations for inner and outer conductor diameters.

	Inner Conductor	
Decimal	**Fraction**	**Metric**
0.15625	5/32	39 mm
0.1875	3/16	47 mm
0.21875	7/32	55 mm

	Outer Conductor	
Decimal	**Fraction**	**Metric**
0.4340	7/16	108 mm
0.5205	33/64	130 mm
0.6071	19/32	152 mm

A MOTORIZED AGITATOR FOR YOUR PRINTED CIRCUIT BOARDS

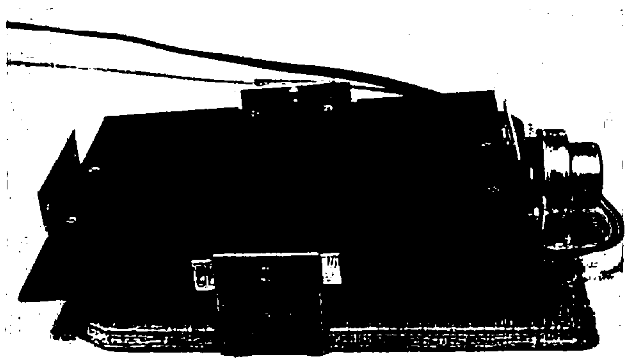
W. C. Cloninger, Jr., K3OF, 4409 Buckthorn Court, Rockville, Maryland 20853

When I first began making printed circuit boards, I placed the unetched board and etching solution in a glass container and agitated the contents by hand. Although the instructions for the ferric chloride etchant indicated a normal etching time of 15 to 20 minutes, I found that it took my boards considerably longer to etch completely — often as long as an hour.

There are three reasons for the extended etching time: (1) the thickness of the copper on the board, (2) the temperature of the etching solution, and (3) the fact that etching time increases noticeably as the etching solution nears the end of its useful life or point of exhaustion. I can't control the thickness of the copper, but I can control the other two variables. To increase the temperature of the etching solution, I place the glass container in a pan of warm water (approximately 100°F). I choose to be a little frugal with the etching solution, because I discard it immediately after use. The rule of thumb is to use 1 ounce of ferric chloride for each square inch of copper, but you can alter this rule depending on copper thickness.

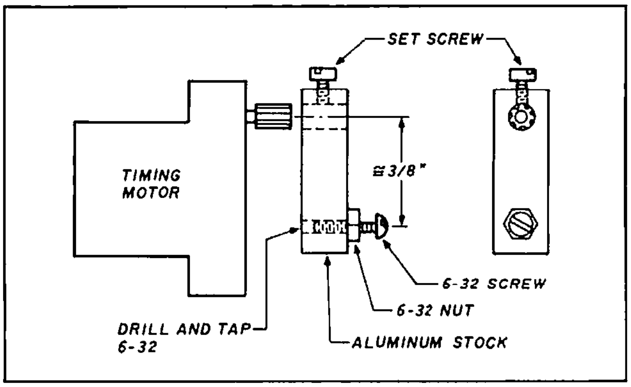
I suspect that my etching times are long because I like to get the maximum out of the etchant. I don't like to discard etchant that's only 50 percent exhausted. The long time required makes it quite a chore to agitate the boards and solution by hand. I mentioned in a previous article on making pc boards[1] that a motorized agitator was one of my next projects. The motorized agitator shown in Photo A is an easy, one-evening project. There's nothing difficult or fancy about its construction.

PHOTO A



Motorized agitator showing simple construction. Rubber inner-tube strips were glued to platform to keep container used for etching from slipping.

FIGURE 1



Details for making a simple crank for installation on the timing motor.

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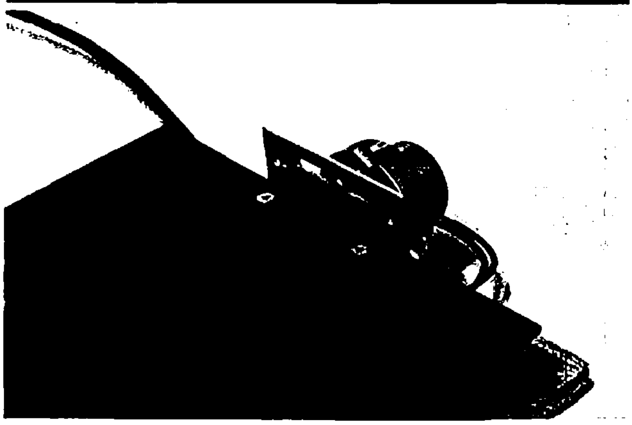
PHOTO B



Closeup of crank and slot mechanism.

The heart of the project is the timing motor. I used a 4-rpm motor from my junkbox (an Olson Electronics special for about 79 cents). There are several suitable timing motors available from H & R Corporation, 401 E. Erie Avenue, Philadelphia, Pennsylvania 19134, for less than $10. Another source is JERRYCO, Inc., 601 Linden Place, Evanston, Illinois 60202. Other hobby and surplus suppliers may have suitable low rpm motors. I don't think you want to go over about 6 rpm because you want to agitage the solution, not slosh it.

The motor is connected to a rocking platform by a crank and slot mechanism. **Figure 1** shows how the crank was made and attached to the motor. **Photo B** shows how the crank is connected to a slotted bracket on the end of the rocking platform. I used aluminum angle stock for the ends and side brackets, and secured them to the masonite platform with pop rivets. A couple of rubber strips from an old inner tube added to the rocking platform keeps the tray or dish from slipping during agitation.

Using the agitator

I have found that it's important to change the position of the etchant container several times during agitation to prevent uneven or incomplete etching. You may also wish to keep the solution warm. I've found that a 100-watt bulb in a photographic reflector placed a few inches above the tray keeps the solution warm during agitation. A heat lamp positioned above the solution would be more than adequate.

This motorized agitator makes it easy to monitor the progress of the board etching, and saves a lot of tedious hand agitation. **hr**

REFERENCES

1. WC Cloninger K3OF "EZ PCBs," 73, August 1987, page 43

HELIUM BALLOON ATV
LAUNCHED OVER INDIANA

ATV technology reaches new heights

William J. Brown, WB8ELK, 12536 T 77, Findlay, Ohio 45840

On June 4, 1988 at 8:58 a.m. CDT, W9PRD (Bob), WB9IHS (Chuck), and I launched a helium balloon Amateur Radio experiment from a grass airstrip 8 miles northwest of Greensburg, Indiana. The balloon package consisted of a 1-watt ATV transmitter (Wyman Research), a computer video I.D. generator with two graphics screens timed in sequence (Elktronics VDG-1), and a half-watt 2-meter FM transmitter sending out a CW I.D.

The balloon system was made up of a 6-foot weather balloon (Kaysam 105G), a recovery parachute, aluminum foil for FAA radar, and the 3-1/4 pound transmitter setup. The 2-meter antenna was a quarter-wave vertical whip; the ATV antenna was an omni-horizontal KS8J "beachball" antenna with two loops at right angles to each other.

The beachball antenna is somewhat directional and has a deep null off the back. As a result, there were deep fades in the ATV picture as the balloon and its cargo spun around. We determined the overall spin rate of the balloon package throughout the flight by observing these fades. The spin rate varied from one revolution every 20 seconds up to four revolutions per second. We plan to eliminate the fading in future flights by using a phasing line to feed one of the loops, making it a true omnidirectional antenna.

A combination of cold temperatures and battery failure caused a WB8ELK flight the previous August to stop transmitting at 70,000 feet, so we started a search for improved insulation and batteries. To better protect the equipment, we made a styrofoam package 2-1/2 inches thick and painted black to absorb solar radiation. Then, WB9IHS found some lithium cell batteries. These SAFT LX 2649 C cells are designed to withstand low pressure and low temperatures. We used ten cells (two chains of five cells). After 8-1/2 hours of continuous drain at 700 mA they still had over 3 hours of life left!

Quite a few ATV'ers from central Indiana were on hand to help us launch the balloon. Larry, WB9YAJ, established a live linkup to the Indianapolis ATV repeater from the airstrip so that anyone within repeater range could view the launch activities. The weather was perfect. When we began inflating the balloon inside an aircraft hanger at 8:30 a.m., there was only a light wind and skies were crystal clear. Mother Nature didn't let us off that easy, however; the winds increased to over 20 mph just a few minutes before launch. Since the balloon was already fully inflated and the winds were fast approaching impossible launch speeds, we decided to send it up before the situation worsened. The balloon flailed around wildly, narrowly missing the hangar door, a telephone pole, and several other sharp objects as we carried our gear about 200 feet onto the center of the runway. Suddenly, the wind died down and the balloon floated straight up lifting the transmitter package off on its journey.

The Indianapolis "Fox Hunters" club had volunteered to be the ground tracking team. They filled six cars and headed off on a chase across southern Indiana, armed with all kinds of direction-finding gear for 2 meters and 70 cm. We were able to watch the balloon for 15 minutes as it headed quickly towards the southwest, rising about 750 feet per minute. Bill, WB9SBY, filmed the launch from a small chase plane for the first few minutes, but the balloon quickly gained altitude on them. We had hoped for some bigger chase planes, but they were all grounded with maintenance problems.

In York, Pennsylvania, WA3USG (Rick) chaired a 40-meter net on 7.155 MHz; N9CJD (George) ran an 80-meter net on 3.871 MHz. The nets received over 80 check-ins and reception reports during the flight. Stations in over nine states received the balloon signals which covered most of the Midwest and part of the South. Operators reported S-meters "pegged" out to nearly 300 miles in all directions. There were many reports of reception on handhelds and scanners over

the same area. W0RPK (Ralph) in Indianola, Iowa was the farthest station to report. He picked up the 2-meter signal at 450 miles. VE3JO and VE3ZK in London, Ontario observed sync bars and a brief, locked picture at a distance of 400 miles. At one point, WB0QCD (Mike) had a P3 to nearly P4 picture at 340 miles. W8YOS near Cleveland had a P2 at 334 miles. WA8KQQ reported a P5 during most of the flight from over 100 miles. In fact, we received several P5 reports from over 100 miles. WB8MSJ (Joe) received P4 signals in full color from 220 miles. Levels of P3 to P4 were seen over 250 miles away by KB9FO (Henry) and N9AB (Andy) in the Chicago area. A brief P5 report came in from K9MTE (Jim) from over 270 miles!

The balloon reached its maximum altitude of 115,000 feet about 2-1/2 hours into the flight. With the exception of an intermittent relay on the 2-meter transmitter, everything was still operating well. We took several internal temperature readings which indicated that the new insulation was working. The temperature was actually over 90° F inside and never seemed to drop below 60 degrees at any time during the flight.

The balloon burst at 11:27 a.m. CDT and started down. Our first indication of the plunge was the rapid fading and flutter on the ATV signal when the package started spinning. The most distant receiving stations started losing the signal rapidly. We estimate that in the near vacuum of 115,000 feet, the package probably dropped at speeds of nearly 700 mph until it was slowed by the parachute at around 50,000 feet. The balloon landed at 11:54 a.m. CDT, after falling for 27 minutes.

Because the jet stream was directly over southern Indiana, the chase team had a real challenge. At times the balloon had been speeding along at over 100 mph. In what might be their "ultimate" fox hunt, the tracking crews were nearly 30 miles from the balloon when it landed. The crews made a dedicated search across a large portion of southern Indiana; the three remaining cars finally got a good fix on the 2-meter signal at 4 p.m. They were about 10 miles north of their quarry when the 2-meter relay stuck again, killing the signal. But as they drove on through a small town, they heard a very weak signal on 439.25 MHz. After driving as far as he could down a dirt road, W9DUU (Paul) started on foot through some incredibly dense underbrush and thorns in the worst possible terrain for direction finding — dense woods and rolling hills! Worried that he might not find his way out again, Paul took one last reading after he'd hacked his way through nearly a mile of woods. At 5:20 p.m. he looked up and saw the balloon hanging 60 feet up in a large tree! The transmitter package was dangling about 20 feet off the ground, still sending out its ATV picture! Paul hooked it with a sapling and brought everything back intact. The balloon landed a mile east of English, Indiana, right in the middle of the Hoosier National Forest, a distance of 86 miles from the launch site!

Except for the fact that the beachball loop antenna now looks like a pair of coat hangers because of its tree landing, the transmitter package will be ready for a repeat flight with a live TV camera. A future flight will carry the first airborne ATV Repeater. The repeater will have a 434 MHz input and 910.25 MHz output; it has the potential of linking up two stations nearly 700+ miles apart!

Special thanks go to everyone who participated in this event. I'd like to thank W9NTP (Don), who let us use his lab very early in the morning on launch day to work on the transmitter package. Don also provided us with the "Mission Control" station where NQ9Q (Brian) and I tracked the balloon. WB9IHS was a great help in choosing the battery system. He also provided up to the minute weather and wind forecasts from the weather bureau via the FAA radio club. Thanks to W9DUU and the Indianapolis Fox Hunters, and of course to W9PRD. His incredible optimism allowed him to predict months in advance that we would have a near perfect launch on June 4 at 9:00 a.m.

I hope these balloon flights will help to increase ATV activity and give us an idea of the possibilites for ATV aboard space shuttles or stations. And who knows, with the experienced launch team we've put together, maybe NASA will give us a chance to help launch the shuttle!

Editor's Note: On January 21, 1989, WB8ELK launched a fifth balloon which carried a small black and white Sony video camera and an Elktronics color video identifier. The balloon rose to a peak height of just over 100,000 feet sending live video pictures of the southern California desert and the curvature of the earth from the edge of space. Bill is considering making his next balloon flight a full ATV repeater.[1]

REFERENCES

1 Fred Maia, W5YI *W5YI Report*, Volume 11 Issue #4, February 15, 1989, page 9

AN RTTY CONVERTER

Almost instant gratification for radioteletype buffs

By Peter Doherty, W1UO, P.O. Box 7252, Greenville, North Carolina 27835

RTTY (radioteletype) has certainly changed in the past few years. Gone are the days of those monstrous mechanical machines, the Model 15, 19, and 28. How many remember the clickety-clack of the old model 15 as it copied the latest W1AW bulletin, sounding like the wire room of some major news network? Well, the whirring of gears and the printing of rolls of hard copy have been replaced by the silence of integrated circuits in the personal computer. Radioteletype has moved from the mechanical into the electronic realm.

One thing hasn't changed, though. The tones that are detected on your receiver can't key your computer directly, just as they can't key a Teletype® machine directly. Likewise, typing on your keyboard won't generate the tones your transmitter needs. As in years past, this is the job of the terminal unit (TU) or converter; MODEM (MOdulator DEModulator) is the modern vernacular.

There are many classic TUs from the vacuum tube era. Old-timers will remember the W2PAT, W2JAV, and the Twin-City converters. How many of you built the one-tube converter and keyer (5763 and 6U8) that appeared in the *Radio Amateur's Handbook* for so many years? The vacuum tube TU has been replaced by integrated circuits that do a better job with less power. Two chips made by EXAR, the XR2206 and the XR2211, replace the 5763 and 6U8. Despite their simplicity, the chips do a surprisingly good job of generating and demodulating RTTY tones. This terminal unit is meant for the beginner or casual RTTY operator who doesn't want to spend a couple of hundred dollars on a little-used converter.

Transmitter converter

The transmitter converter is built with an EXAR monolithic function generator chip, the XR2206. The generator tone frequency is determined by C6 and R1 or R2 (see **Figure 1**). Depending on the state of pin 9 on the XR2206, R1 or R2 is part of the frequency-determining circuit. For instance, with pin 9 high, R1 is in the circuit and a 2295-Hz space tone is generated. With pin 9 low, R2 sets the mark tone to 2125 Hz. Potentiometer R4 sets the output level of the audio tones at pin 2.

U3a acts as a buffer and inverter between the outside world and the XR2206 chip. Inverters are handier than straight buffers in this application; they make it easier to invert logic signals so that tones and LEDs run "right side up." LED CR1 blinks in time with the incoming data from the computer. You can see when the computer has finished sending, so that you don't switch to receive prematurely. R3 sets the distortion of the chip to a nominal value. If you're a purist you may want to substitute a 500-ohm potentiometer and adjust it for minimum distortion on an audio analyzer. Then you can plug the audio tones into an HF SSB or VHF/FM rig.

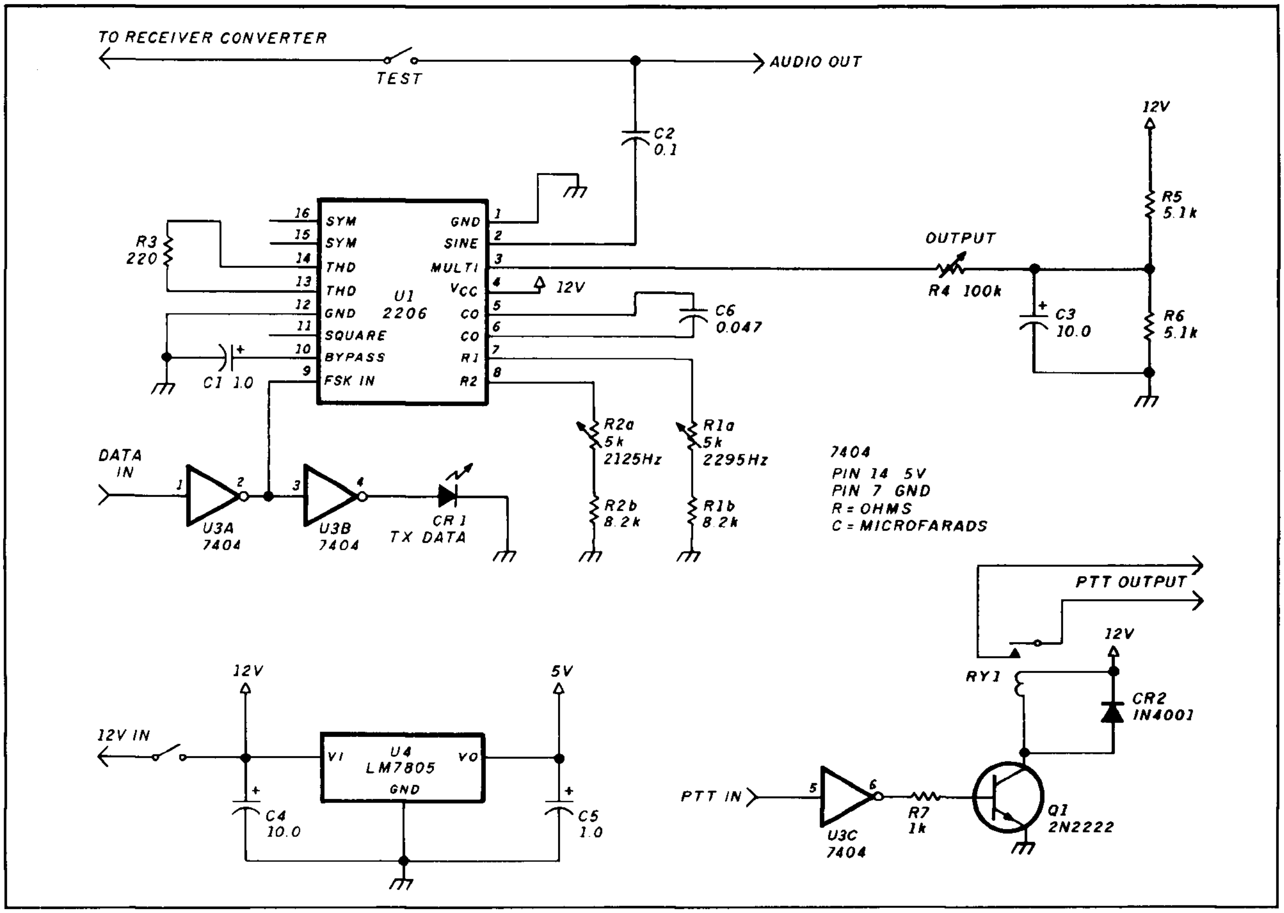
Figure 1 also shows a simple push-to-talk (PTT) interface for use between your computer and radio. PTT data from the computer is buffered and inverted by U3C and drives Q1 and RY1. I opted for a reed relay here because many rigs have different keying voltage requirements, and the reed relay will key just about any rig. If you find that your software is in the receive mode but the PTT relay is keyed, simply add another 7404 inverter in series with U3C to get the PTT signal right side up.

The converter is powered by a plug-in 12-volt DC supply. The 7805 IC regulates this voltage to 5 volts for use by the XR2211 and 7404.

Receiver converter

The receiver converter in **Figure 2** is designed around the EXAR XR2211 FSK (frequency shift keyer) demodulator chip. Audio from the receiver's speaker or phone jack is routed to pin 2 of the XR2211 through C7. Audio from the transmitter converter can also be applied to this point through a test switch to test the transmit/receive converter combination. C9 and R16 set the center frequency of the converter. For mark/space tones of 2125/2295 Hz the center frequency is 2210 Hz. Resistor R14 or R15 in series with R13 set the bandwidth of the

FIGURE 1



Schematic of the transmit converter portion of the circuit.

TABLE 1

Receiver modem calculations
2125/2295 Hz, 170-Hz Shift
Center frequency
fo = (2125+2295)/2 = 2210 Hz
Choose value of R16
R16 = 20 k (18 k + 5-k pot)

Calculate C9

C9 = 1/(fo × R16)
= 1/(2210 × 20000)
= 0.0000000226
= 0.022μF

Calculate Rshift (R13 + R14)
Rs = R16(fo/FSK shift)
= 20000(2210/85) = 520 k
= 20000(2210/170) = 260 k
= 20000(2210/425) = 104 k
= 20000(2210/850) = 52 k

Calculate C12
C12 = C9/4 ≈ 0.005μF
All values are rounded to nearest standard component values.

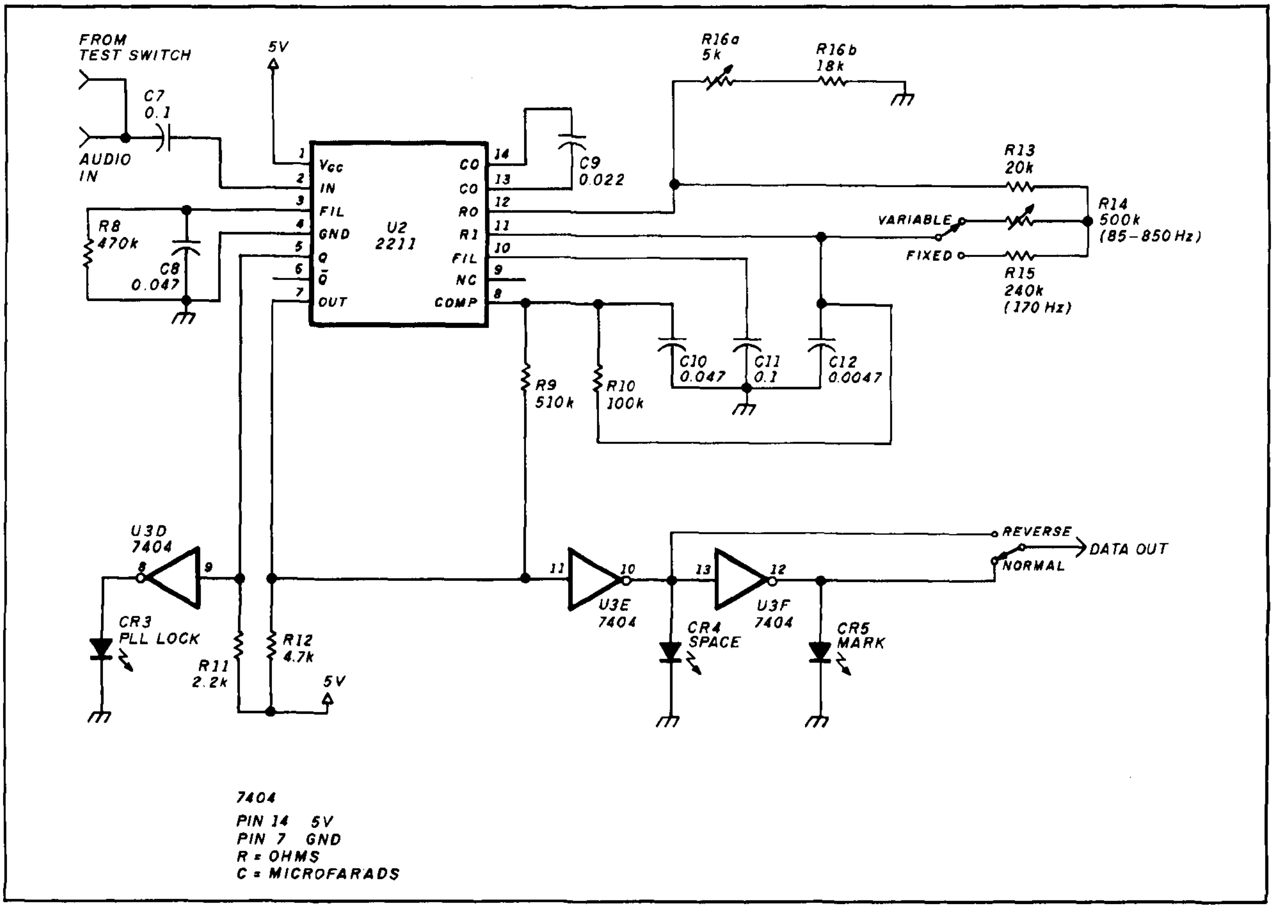
Transmitter modem calculations
F1 = 2295 Hz F2 = 2125 Hz
Choose a value for R1 and R2
R1 and R2 = 10 k (8.2 k + 5-k pot)
Calculate C6
C6 = 1/(R1 × fo)
= 1/(10000 × 2295)
≈ 0.000000044
= 0.047μF (standard value)

Check values of R1 and R2

R1 = 1/(C6 × fo)
= 1/(0.000000047 × 2295)
= 9.27 k
R2 = 1/(0.000000047 × 2125)
= 10.01 k

R1 and R2 fall within
range of 8.2-k resistor
and 5-k pot

FIGURE 2



Schematic of the receive converter portion of the circuit.

XR2211; hence the shift of the RTTY signal to receive.

R15 copies a fixed shift of 170 Hz; potentiometer R14 allows you to copy shifts from 85 to 850 Hz. This comes in handy when you leave the Amateur bands to explore RTTY on the commercial bands. CR3 indicates if the phase-locked loop (PLL) is locked onto the RTTY signal, CR4 shows that a space signal is being received, and CR5 indicates the same for the mark signal. Data out is routed through a SPDT switch making normal/reverse data available. This is helpful on the commercial bands, as many stations use tones inverted with respect to the Amateur standard.

Design notes

It's easy to design the converter for other frequencies. **Table 1** gives most of the necessary formulas. I've worked these calculations for frequencies of 2125/2295-Hz and 170-Hz shift. Just substitute the new audio tones and shift, and select the nearest standard component values. The potentiometers give you some leeway in the selection of the frequency-determining capacitors. Note that the signals to and from the converter are transistor-transistor logic (TTL) level; that is, 0 and 5 volts. If your computer uses different levels, like RS-232 (−12 and +12 volts), you must change these voltages before applying them to the converter. For the RS-232, a set of 1488/1489 line driver/receiver chips designed for this purpose will do the job. An even better choice would be the Maxim MX232, as this chip doesn't require an external negative bias supply. You can find information on using these chips in their data specification sheets.

Construction

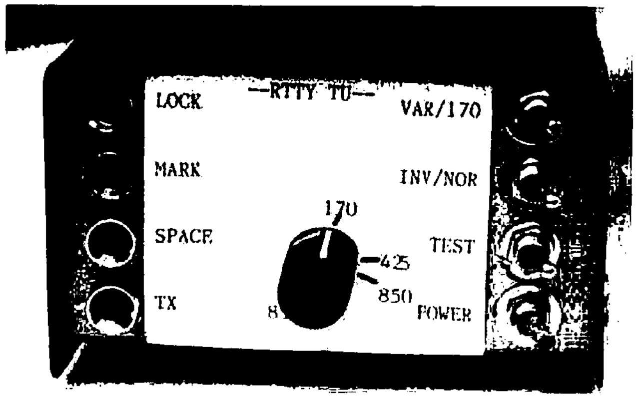
All the components to build the converter are available from Radio Shack, Jameco, or Digi-Key. For the best frequency stability, choose polystyrene or some other stable type for frequency-determining capacitors C6 and C9. These are sometimes hard to find; check the flea markets. I have used Mylar™ capacitors with good results. R1a, R2a, and R16a should be ten-turn pots to allow precise setting of the tone frequencies. The backlash of a normal pot will drive you crazy!

I built my converter (see **Photos A** and **B**) on a Radio Shack prototype board and mounted it in one of their little metal cases. I mounted variable shift potentiometer R14 in the center of the front panel. Four LEDs, indicating lock, mark, space, and TX data are mounted on one side of the front panel. On the other side I put the four switches for power, normal/reverse, variable/170-Hz shift, and test. The wiring is audio level and not too critical. You may want to consider using ferrite beads or bypass capacitors, or both, on the computer leads to keep

PARTS LIST

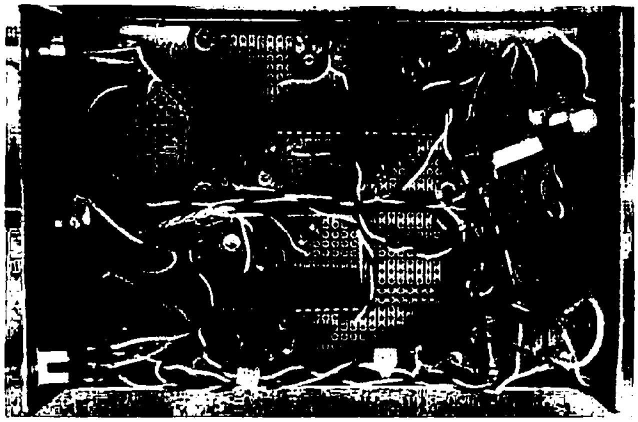
	Description
CAPACITORS	
C1,C5	1.0-μF tantalum
C2,C7,C11	0.1-μF Mylar
C3,C4	10-μF electrolytic
C6	0.047-μF polystyrene or Mylar
C8,C10	0.047-μF Mylar
C9	0.022-μF polystyrene or Mylar
C12	0.0047-μF Mylar
DEVICES	
U1	EXAR XR2206
U2	EXAR XR2211
U3	LM7404
U4	LM7805
CR1,CR3,CR4,CR5	LED, panel mount
CR2	1N4001
RESISTORS	
R1a,R2a,R16a	5-k ten-turn pc pots
R1b,R2b	8.2 k
R3	220
R4	100-k pc pot
R5,R6	5.1 k
R7	1 k
R8	470 k
R9	510 k
R10	100 k
R11	2.2 k
R12	4.7 k
R13	20 k
R14	500-k pot
R15	240 k
R16	18 k
MISCELLANEOUS	
Switches	
SPDT	two each
SPST	two each
RY1	Reed relay, 12 volt
Q1	2N2222A

PHOTO A



The completed converter.

PHOTO B



Internal view of the converter.

the computer interference out of your radio and vice versa. I didn't find this necessary in my application.

Lacking a better method, I typed the front panel label on heavy card stock and attached it to the front panel with wide, transparent packing tape. It's crude but effective. I just couldn't picture myself squeezing all those rub-on letters into such a small place.

Alignment

The easiest way to align the transmitter section is with a frequency counter. Connect pin 1 of the 7404 to 5 volts through a l-k pull-up resistor (pin 9 of the XR2206 goes low) and adjust R2a for the mark tone of 2125 Hz. Ground pin 1 of the 7404 (pin 9 of XR2206 goes high) and adjust R1a for a space frequency of 2295 Hz. If your software has inverted mark/space tones, adjust R1a for the mark tone and R2a for the space tones.

If you don't have a frequency counter, you can use an audio source of known calibration and an oscilloscope. A calibrated converter from a friend would be a good source. Feed the calibrated tone into the horizontal amplifier and feed the uncalibrated tone into the oscilloscope vertical amplifier. Now adjust the proper pot in the converter until the pattern becomes a perfect circle, indicating that the tones are the same frequency. Do this for the mark and then the space frequencies. (These oscilloscope patterns are called Lissajous figures: the technique is described in any radio handbook.)

To calibrate the receiver, first set the fixed/variable switch to the fixed position. Next, connect an ohmmeter to read the combined resistance of R13 and R14. Adjust R14 to full resistance (a combined total of 520 k) and mark the front panel knob for 85-Hz shift Now adjust R14 for a total of 260 k and mark the panel for 170-Hz shift. A resistance of 104 k equals a shift of 425 Hz and a resistance of 52 k equals a shift of 850 Hz. These are the most commonly used shifts on the shortwave bands. (This adjustment isn't very important.) With the fixed/variable switch in the fixed position and no signal present, disconnect C8, short pin 2 to pin 10 of the XR2211, and attach a frequncy counter to pin 3. Set the frequency to the center frequency (2210 Hz) with potentiometer R16a. Remove the short and reconnect C8. As before, if you don't have a frequency counter, feed a known RTTY signal into the input and adjust R16a for a clean copy on your computer.

Operation

Once the tones are adjusted in the transmit portion, the only other adjustment you need to make is to the output level. R4 takes care of this. Set your software into the transmit mode and feed the tones into the mic jack of your transceiver through the appropriate connector. You should be in LSB mode. Set R4 to midscale. Now adjust the mic gain on your rig, along with R4 for the proper RF output level on your transceiver. Remember that RTTY is a 100-percent duty cycle mode, and many transceivers are not designed for continuous output. You may have to back down on the output until you attain a safe level. In an FM radio you just have to adjust R4 until you reach the proper deviation without clipping in the mic circuit.

To tune in an RTTY signal, first check out the ham bands around 3.6 or 14.1 MHz where most signals will be operating 170-Hz shift. As you tune through an RTTY signal, the PLL lock, mark, and space lights will flicker. As you approach the center of the signal, the PLL lock light will suddenly glow with full brilliance. The mark and space lights should be flickering evenly. A slight adjustment of the VFO on your receiver will result in copy on your computer screen.

If the lock light is lit and the mark/space lights are flickering but you don't have clean copy, try the normal/reverse switch. If you are properly tuned to an RTTY signal that's not keying, the PLL lock and mark lights should be lit. If you're new to RTTY, it will take a while to get the hang of tuning in the signals. It may also take a while to get all the software and converter connections running right side up, using the proper options of your software and/or inverters in your converter. On FM, it's only a matter of adjusting R16a on the receiver converter until clean copy occurs while receiving an RTTY signal.

When you start cruising the shortwave bands in search of commercial stations, operation will take a little more savvy. Here are a few hints. You probably won't know the shift of the shortwave station. Tune in the signal until the tones sound "about right." Flip the fixed/variable shift switch to variable. Then rock the variable shift potentiometer until the PLL lock lights and the mark/space lights blink evenly. Odds are good that the station will be running one of the standard shifts marked on the front panel. Now it's time to try the normal/reverse switch and different speeds in your software. After a short time, you'll be able to recognize the shift, the speed, and whether the RTTY signal is in Baudot or ASCII simply by the sound.

Concluding remarks

If you're just interested in listening, it's not necessary to build the transmit section. The receive converter is a simple device. It won't rival a full-blown unit with separate mark and space filters. However, it does a good job on the crowded Amateur bands — as long as the interference isn't too severe. Commercial stations tend to operate on clear channels, so the results with these have been very good. Of course, the quiet environment of VHF/FM is the ideal situation for this converter. Despite the fact that an RTTY contest on 20 meters on a Sunday afternoon will probably crush the little converter, I've had many enjoyable QSOs on both 20 and 80 meters in less than clear channel situations. I have also used it to copy bulletins in ASCII from W1AW. I use this converter with a Commodore 64 and Kantronics Hamsoft Software. Gone is the mechanical thunder of the Model 15. hr

THE NO5H
ALL-BAND DIPOLE

Easy to build, easy to move antenna

Gary L. Elliott, NO5H, 41200 Highway 933, Prairieville, Louisiana 70769

My line of work requires that I move to a new location every four or five years. This means I'm continually taking down or putting up antennas. As a result of this, I am always looking for a wire-type antenna that's easy to construct and get working.

I enjoy working all the HF bands from 160 through 10 meters and do most of my operating on 160 and 40 meters. My goal was to design a coax-fed dipole antenna that was simple to build and fit into a 198-foot space.

Description

My antenna design is neither new nor unique. But I've never seen it written up in any of the Amateur publications.

I built a 3/2-wavelength dipole cut for the center of the 40-meter band and fed with 75-ohm CATV coax through *a half-wave matching* section of 300-*ohm or* open-wire line. Why a 3/2 antenna cut for 40 meters? I wanted an antenna that would operate on 160 meters as a dipole, and in an inverted "V" configuration. I didn't want to resort to traps or to tying the feeder wires together, as you would when using a short dipole as a "T"-type antenna. I wanted the advantage of a dipole, in a length shorter than full dipole size.

If the antenna I've described sounds like a G5RV-based design, it should. The G5RV is also a 3/2-type dipole, except that Louis Varney, G5RV[1] designed his dipole to a 3/2 wavelength at a frequency of 20 meters. Like the G5RV, my antenna is an all-band 160 through 10 design, but it has certain advantages because of the longer length of the dipole. This longer length allows full-dipole and/or long-wire performance on all bands from 160 through 10 meters; you don't need to tie the feeders together for 160-meter operation.

Operation

The NO5H antenna operates in the following configurations on the accompanying bands:

- shortened half-wave dipole on 160 meters
- two half waves in phase on 75 meters
- a 3/2-wavelength dipole on 40 meters
- two full waves in phase on 30 meters
- two long wires each 3/2 wavelengths long on 20 meters
- two long wires each 2 full wavelengths long on 15 meters
- two long wires each 5/2 wavelengths long on 12 meters
- two long wires each 3 full wavelengths long on 10 meters

All-band coverage (including the two usable WARC bands) is achieved easily with this simple antenna configuration.

Construction

The flat-top portion of the antenna is 203′ long; each half of the flat top is 101′6″ in length. The formula I used is:[2]

$$L = \frac{1451.4}{f\ (MHz)} \qquad (1)$$

The matching section is made from 53′6″ of 300-ohm twin lead with a velocity factor of 82 percent (in my case). When the formula is used this way it becomes.[3]

$$L = \frac{468}{f\ (MHz)} \times .82 \qquad (2)$$

I used a run of 75-ohm CATV RG-6 coax to the antenna tuner in the station.

This antenna design has some unique features that set it apart from similar antennas. I use CATV RG-6 coax with 100-percent aluminum shield,* along with a long shank F-type cable connector at both ends of the coax. The F-type connector requires the use of a compound jaw crimping tool. The antenna is as simple to build as any other dipole, and using F-type connectors on the coax makes the assembly process even easier.

*Radio Shack, RG-6 CATV coax p/n 278-1324.

Once the 203′ flat top is laid out and the center insulator installed, attach the 53′6″ matching section by soldering it in place at the center insulator. I installed an SO-239 chassis connector at the other end of the matching section. One wire of the matching section is soldered to the center pin and the other to a solder lug bolted to one of the corner mounting holes. The connection needs to be sealed from the weather by whatever means you generally use. I installed a long shank F-type connector** on the end of the RG-6 coax and coiled the coax into a 6″ diameter 11-turn choke coil. Then I attached a female F to PL-259 adaptor*** to the F connector on the RG-6 coax. This lets you run the coax to the station antenna tuner after the antenna is raised to its operating position. When you connect the coax at the station end it's good to allow a little extra; you may have to shorten the coax run a bit if you encounter a hard-to-load condition on one band. **Figure 1** gives dimensional details for the antenna.

Some of you many wonder why I used CATV-type RG-6 coax and F connectors for an Amateur antenna project. The better quality RG-6 has the same loss per hundred feet as RG-213 coax and lower loss than RG-8X coax at a cheaper price per foot than the others. RG-6 cable is also 100 percent shielded. The coax has an aluminum shield which is not intended to be soldered, and that's why I used the F connector. Using this connector at the 200-watt level hasn't presented a problem. In fact, using the crimp on the long shank F connector makes trimming the lead-in much easier if a loading problem occurs on one of the bands in use.

I think we all need to be more innovative when it comes to antennas and feed systems. Those who operate at VHF and UHF learned long ago to use CATV hardlines and cables because of the lower loss. Fifty ohms doesn't have to be the magic number for most applications. Many stations now use antenna tuners or rigs with built-in tuners to control the SWR that their solid-state rigs feed into. So don't be afraid to give other cables or connectors a try; you may find that they do make antenna projects easier and more fun.

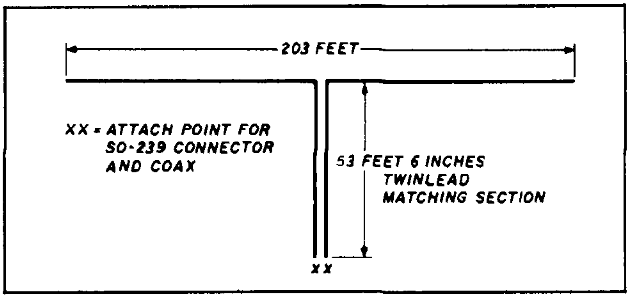
Conclusion

The antenna can be mounted either as a horizontal dipole or an inverted V. In my case, the antenna is in the inverted Vee configuration with the apex at about 50 feet and the ends of the antenna about 10 feet off the ground.

Does it work? Comparisons with my regular G5RV show improvements on all bands. The greatest are seen on 30 through 10 meters. On 40 and 80 meters I find that the improvement depends on the distance and propagation of the signal being received.

One thing I can't stress enough is that both this design and the G5RV require the use of an antenna tuner. Take time to read Louis Varney's comments on the G5RV design in the *ARRL Antenna Compendium, Volume One.*[4] Even at the 3/2 design frequency with the half-wave matching section, the feedpoint impedance is still a little over 100 ohms. Oh the other bands the feedpoint impedance varies because of the complex loads presented by the antenna, resulting in the need for an antenna tuner. My design and the G5RV are efficient all-band antennas that can be coax fed.

FIGURE 1



Dimensional details of the NO5H all-band antenna.

REFERENCES

1. Louis Varney, G5RV, "The G5RV Multiband Antenna ...Up to Date," *The ARRL Antenna Compendium, Volume 1*, 1985, page 86-90.
2. Bill Orr, W6SAI, "Ham Radio Techniques: The G5RV Explained," *Ham Radio*, February 1985, page 59.
3. Louis Varney, G5RV, ibid., page 89.
4. Louis Varney, G5RV, ibid., pages 86-90.

**Radio Shack, gold-plated CF-56 type F connectors p/n 278-225
***Radio Shack, PL-259 plug to female F connector p/n 278-258.

PRODUCT REVIEW

Digitar's Model PCW Weather Station

Now you can have your own advanced computer weather station. Digitar's Model PCW automatically monitors and tracks local weather conditions on your MS-DOS computer.

The weather station comes with a wind vane and speed sensor and all mounting hardware. Also included are two remote temperature sensors, a plug-in computer card, basic operating software, 12 volts AC power adapter, and complete documentation. The PCW's VLSI onboard microprocesser generates instant weather data on the computer screen. It shows current temperature (inside/outside); barometric pressure; wind speed, chill, gust, and direction; high and low temperature over a 24-hour period; and clock calendar. An optional rain collector is also available.

The PCW has programmable alarm set points for time, high wind speed, and high and/or low temperature. When any set points are reached, the PCW card sounds an alarm (even when the computer is shut off) using its own power supply.

The optional PCWPRO software package, an advanced controller, makes the PCW weather station a sophisticated monitoring and data logging program. It can display each function in graphic form and saves data to disk on the hour and half hour. Both the PCW and the PCWPRO can be placed in the computer's background to allow use of your PC for other functions, such as logging QSO's or word processing. You can return to it by typing a user-selected key sequence.

The instructions were extremely easy to follow, explaining in simple terms how to configure the board to work with your PC. The PCW plug-in board accommodates different computer configurations.

The enhanced PCWPRO software is designed with open architecture and predefined system calls. User-written programs may be designed to interface the PCW Weather Station with other computer applications.

The PCW weather station sells for $299, the PCWPRO enhanced software for $99.95, and the optional RG-2 rain collector for $49.95. All are available from Azimuth Communications, Corp., 11845 W. Olympic Blvd., Suite 1100, Los Angeles, California 90064.

de N1GCF

Circle #301 on Reader Service Card.

Ameritron RCS-4 and RCS-8V

Over the last ten years, the price of coaxial cable has jumped significantly due to the high cost of raw materials. Hams with long, multiple feedlines know how expensive several runs of coax can be.

However, Ameritron has two ways to overcome this problem. The RCS-4 will switch four antennas and doesn't require extra cabling to operate. The RCS-8V switches five antennas and requires an external control cable.

The RCS-4 is elegant in its simplicity. The relay box contains three relays that are switched by voltages fed through the coaxial feedline. With no voltage present, the antenna selected is no. 4. As you switch to the other antennas from the control box, either DC +, DC −, or AC is fed into the coax to turn on the appropriate antenna relay.

Three 0.01-μF capacitors and a radio frequency choke isolate the station from the antennas at the control box and the relay voltages from the antenna lines. The three relays have 10-A contacts and are rated at 50-ms switching time. A small air spark gap is mounted on the relay box circuit board to bleed off any static charges that could accumulate. Additional lightning protection is recommended through coax loops on all feedlines.

To use the RCS-4, insert the control box into your shack's feedline just before it goes outside and connect the relay box to the end of the feedline. Connect your antennas to the relay box and you're ready to go! The antenna selector switch has red LEDs that indicate which antenna is selected. Make sure that the relay box is installed with the connectors down and that you do not attempt to further weatherseal the unit. Water will accumulate if you do, and eventually the unit will have problems. The relay box can be mounted anywhere that's convenient for you. Its rugged construction ensures you'll have minimal problems after installation.

Insertion loss is less than 0.05 dB under 30 MHz and the insertion VSWR is under 1.1:1 from 1.8 to 30 MHz. The unit is designed to handle 1500 watts and 2500 watts PEP maximum. One word of warning — never attempt to switch while transmitting! If you do, you risk losing the switch.

The RCS-8V gives you several advantages over the RCS-4. It will handle greater power, it's rated at 4 KW below 30 MHz (1 kW PEP at 148 MHz), and works from 1.8 to 220 MHz with negligible insertion loss and only a slight additional loss at 450 MHz. This greater flexibility is gained through use of an external control line to switch antennas.

You can use any wire to control the switch. As long as the conductor to ground return resistance is less than 80 ohms, the unit will operate normally. Five or 8-conductor rotor wire is usually the easiest to get and use. To set up the switch connect at least a 5-conductor control cable between the relay box and the control box in the shack. (Make sure that the wires are connected in proper sequence.)

The RCS-8V gives you the ability to select more than one antenna at a time. For instance, if you're running stacked beams, you can wire the switch to select either the upper or lower antenna or for additional gain, or both antennas at the same time. The switch can also be used to select either five antennas for one rig or five rigs for one antenna. Versatility is limited only by your needs.

The RCS-8V will switch in less than 50 ms and uses heavy-duty 10-A rated relays. The relays are isolated so that you can switch two antennas simultaneously. However, I recommended that you ground the antennas when they're not in use. Ameritron provides the information on how to modify your switch.

These two products are constructed from high quality rugged parts and will give years of service. The relay boxes for both the RCS-4 and RCS-8V are made from steel enclosures for 100-percent shield coverage and TVI/RFI protection. Whatever your needs, one of these two switches will work for you. See your local Ameritron dealer for more information.

de N1ACH

Circle #302 on Reader Service Card.

Cushcraft A4S four-element, HF Triband Yagi antenna

Looking for an antenna to maximize your signal on 20 through 10 meters? Cushcraft's A4S four-element tribander is more than up to the task.

In keeping with Cushcraft's history of high-performance HF Yagis, the A4S is a true winner. Offering triband coverage with three elements each on 10, 15, and 20 meters, the A4S has been optimized to provide excellent

(continued on page 86)

(continued from page 84)

bandwidth (greater than 500 kHz on 10 meters) and the maximum obtainable gain and F/B ratio. Cushcraft rates the antenna at a nominal 8.9 dBd of forward gain and 25 dB front-to-back ratio. The maximum power rating is 2000 watts PEP.

Construction of the A4S is simple and straightforward when you use the instructions included with the antenna. The 18-foot boom comes in three 6-foot sections. The stainless steel hose clamps and bolts provided to pin the sections prevent boom rotation. The elements are constructed of telescoping lengths of aluminum, weatherproof traps, and stainless steel hardware for a rugged and durable installation. It took us just under an hour to put the antenna together.

Replacing HAM RADIO's 12-year-old antenna with the new A4S took only a half hour. The A4S weighs 37 pounds and can be handled easily by one person. A light and manageable antenna is always a joy for working on a tower and the A4S is no exception for ease of installation.

Cushcraft also has an add-on kit available for 40 and 30 meters. The additional traps are installed at the end of the driven element. The kit is then set for either 40 or 30 meters.

Our old Cushcraft antenna had always held its own, both in DX pileups and in stateside QSOs. The new A4S has demonstrated that it is capable of maintaining the performance tradition. Band conditions permitting, I was effortlessly able to work anything I heard. If you are looking for good performance, the A4S is an excellent choice. Retail price is $525.

de NB1H

Circle #303 on Reader Service Card.

NEW PRODUCTS

UI-7 FM module for IC-725 and noise-reducing power cord

The UI-7 is an FM module which allows AM transmit with the IC-725 transceiver. Suggested retail price is $71.99.

Also available is the CP-11, a cigarette lighter power cord with a built-in noise reduction filter. Suggested retail price is $18.99.

Contact ICOM America, Inc., 2380 116th Avenue N.E., PO Box C-90029, Bellevue, Washington 98009-9029.

Circle #304 on Reader Service Card.

New Software for MN and Yagi

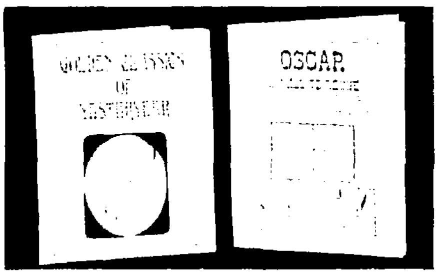
The new MN (enhanced version of the U.S. Navy's MININEC) program for IBM-PC and compatible computers will analyze almost any antenna made of wire or tubing. MN computes antenna forward gain, front-to-back ratio, beam width, sidelobes, angle of radiation, current, impedance, SWR near fields, and far fields. Antennas may be modeled in free space or over real earth. It plots antenna radiation patterns in polar or rectangular form on CGA, EGA, or HGC graphics screens. Hard copies of the plots may be made for nearby antennas or structures, allowing detailed analysis of stacked arrays. The 5-1/4 inch MN disk contains over 100 files, including libraries of antenna and plot files, a file editor, and documentation. The program costs $75 ($80 in Canada and foreign countries).

YO Yagi Optimizer Software

The new YO program for IBM-PC and compatible computers automatically adjusts the element lengths and spacings of a Yagi design to maximize forward gain, optimize pattern, and minimize SWR. Radiation patterns at the center and edges of a band, and a scale drawing of the antenna, are plotted on CGA, EGA, or HGC graphics screens during optimization. Hard copies of the plots may be made on dot-matrix printers. YO computes several trial designs per second for small Yagis, with an optional math co-processor chip installed. Yagis of up to 50 elements may be modeled. The YO design package includes models for gamma and hairpin matching networks, element tapering, mounting plates, and frequency scaling. A library of Yagi files and documentation are included. The program costs $90 ($95 in Canada and foreign countries).

These programs are available from Brian Beezley, K6STI, 507-1/2 Taylor Street, Vista, California 92084

MFJ Offers Two New Books



MFJ offers two new books by Dave Ingram, K4TWJ.

In *Golden Classics of Yesteryear*, you'll find real-life tales, and information on transmitters, receivers, favorite circuits, telegraph keys, bugs, and other ham radio topics. It contains easy-to-build weekend projects from the 1920s, '30s, '40s and '50s.

K4TWJ even shows you how to build a classic "Tailender" an early DX memory keyer that requires no power supply or other electronic parts and works like a champ. Ingram, a collector of classic radio gear, shows you how to collect, restore, and operate it.

OSCAR Satellite Revue is an anthology of CQ magazine articles about setting up and operating various types of OSCAR stations for working DX, as well as Japanese and Russian satellites. Each article is followed by an update and ready-to-use frequency conversion charts for all satellite modes. There are tracking notes for OSCAR 13, OSCAR 10, Japanese JO-12, and Russian RS-10/RS-11.

K4TWJ even shows you how to work the Russian robot on RS-10 and exactly how to receive a QSL card confirming this rare DX!

There's a quick-start guide for newcomers and an equipment review section. Also included is up-to-date Keplerian data for computerized tracking programs.

For more information contact MFJ Enterprises, Inc., PO Box 494, Mississippi State, Mississippi 39762. Phone: (601)323-5869. To order call toll free (800)647-1800.

Circle #305 on Reader Service Card.

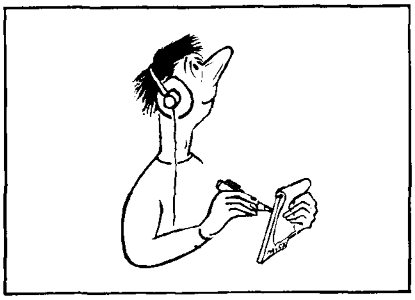
Davis RF

Davis RF has a new wire for dipole/long wire antenna applications. This wire is custom made for strength and will not stretch under normal ham applications, including counterweights. The wire is no. 14, multistranded copper. It will not kink or unravel, is extremely flexible, can be tied in knots, and is easy to solder.

A complete catalog of antenna parts is available from Davis RF, Box 230 Carlisle, Massachusetts 01741. Phone (508) 369-1738

Circle #306 on Reader Service Card.

DX Forecaster



Garth Stonehocker, KØRYW

SPORADIC E BASICS FOR 1989

What will the sporadic E propagation conditions be as the maximum of solar cycle 22 approaches? From May through September radiation from the nearly overhead sun generates high ion densities in the lower ionosphere that support short-skip propagation — including multiple short skips. The geomagnetic field clusters these ions into cloud-like patches known as sporadic E (E_S). These patches form a thin layer of intense ionization in the E region about 60 miles up. A patch gives a strong, mirror-like signal reflection over skip distances of 600 to 1200 miles. This lasts for perhaps an hour

The frequency and magnitude of Sporadic E occurrences are functions of geographical location. The best locations for summer E_S openings are on either side of the geographic equator, at the point where the geomagnetic equator is farthest away. This condition occurs in the Northern Hemisphere in Southeast Asia (best) and the Mediterranean (next best). In the Southern Hemisphere it occurs in South America. The highest frequency propagated by E_S tends to occur at local noon. Since the E_S patch is embedded in the regular E layer, it tends to track the E maximum ion density throughout the day, season, and sunspot cycle. This summer you can expect an increase in the E layer as an E_S base for higher maximum usable frequencies (MUFs) over a 1200-mile hop. This increase will give base MUFs of 51 to 57 MHz this year, so 6-meter openings should be really good. The highest probability of occurrence is near sunrise and again around sunset. These two E_S characteristics affect short-skip openings differently. Openings on the higher frequency bands occur around local noon; the lower bands tend to have openings near sunrise and sunset. This characteristic is nearly constant over the sunspot cycle so there should be the same number of low to midlatitude E_S openings, but the MUF is up for better DX. More about E_S next month.

Last-minute forecast

Openings on the higher frequency bands (10 to 30 meters) are expected to be best the last two weeks of the month. At the same time, signal strengths will be lower then normal. Both are conditions of the increased MUF from the 27-day solar flux maximum expected at that time. Solar flare geomagnetic disturbances are expected around the 19th and 27th; another disturbance may result from thin corona near the 9th. These will lower the MUF by 15 to 25 percent. Because these effects are worse on evening paths, the lower frequency bands will experience more fading and much lower signal strengths. Otherwise, the lower bands should be best the second week of June.

The moon will be full on June 19th and at perigee (its closest approach) on June 28th. Summer solstice is on the 21st at 1100 UTC. The Aquarid meteor shower starts about the 8th, peaks around the 28th, and lasts until about August 7th. The maximum radio-echo rate will be 34 per hour.

Band-by-band summary

Six meters will provide occasional openings to South Africa and South America around noontime via short-skip E_S propagation. There will be long-skip conditions on 10 meters in the afternoon during the peak times of the 27-day solar cycle. Otherwise, look for sporadic E short-skip and multihop openings around local noon for DX on this band. (Evening transequatorial openings usually don't occur in the summertime.) Twelve, 15, and 17 meters (almost always open to some southern part of the world) will be the main daytime DX bands. Operate on 12 first and then move down to 15. DX is considered 5000 to 7000 miles on these bands. There may be some long, one-hop transequatorial propagation paths occurring early in the month.

Twenty, 30, and 40 meters will support DX propagation from most areas of the world during the daytime and into the evening hours on most days. DX on these bands may be either long skip to 2500 miles or short skip E_S to 1250 miles per hop. There are many good hours of DXing ahead because the days are longer.

Thirty, 40, 80, and 160 are all good for nighttime DX. Although the background thunderstorm noise will be noticeable, these bands are still quiet enough to provide good DX-working conditions. Sporadic E propagation may be a contributing factor toward enhanced conditions at local sunset, and will occur more often during the next three months. hr

WESTERN USA

GMT	PDT	N ASIA FAR EAST	NE EUROPE	E S. AFRICA	SE S. AMERICA	S ANTARCTICA	SW NEW ZEALAND	W OCEANIA AUSTRALIA	NW JAPAN
0000	5:00	12	17	15	10	12	10	10	12
0100	6:00	12	20	17	10	12	10	10	10
0200	7:00	10	20	17	12	15	10	10	10
0300	8:00	10	20	17	12	15	10	10	10
0400	9:00	12	20	17	15	20	10	10	10
0500	10:00	12	17	15	15	20	10	10	12
0600	11:00	15	15	12	15	20	10	10	12
0700	12:00	15	17	12	17	20	10	12	12
0800	1:00	17	17	15	17	20	10	15	15
0900	2:00	17	20	20	17	20	12	15	15
1000	3:00	20	20	15	20	20	12	20	15
1100	4:00	20	15	12	20	20	15	17	20
1200	5:00	30	15	12	15	30	15	17	20
1300	6:00	15	15	10	12	30	20	20	20
1400	7:00	15	12	10	12	30	17	20*	17*
1500	8:00	15	12	10	10	30	17	20	17
1600	9:00	15*	10	10	10	30	17	20	30
1700	10:00	17	10	10	10	30	15	20	20
1800	11:00	17	10	10	10	20	12	20	17
1800	12:00	20	10	10	10	15	10	10	15
2000	1:00	20	12	12	10	15	10	10	15
2100	2:00	17	12	12	10	12	10	10	12
2200	3:00	15	15	15	10	12	10	10	12
2300	4:00	15	17*	15	10	12	10	10	12

MID USA

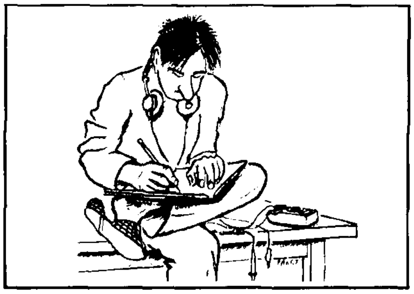
GMT	MDT	N ASIA FAR EAST	NE EUROPE	E S. AFRICA	SE S. AMERICA	S ANTARCTICA	SW NEW ZEALAND	W OCEANIA AUSTRALIA	NW JAPAN	CDT
0000	6:00	17	17	15	10	12	10	10	10	7:00
0100	7:00	17	20	17	10	12	10	10	10	8:00
0200	8:00	15	20	17	12	15	10	10	10	9:00
0300	9:00	12	30	17	12	15	10	10	12	10:00
0400	10:00	12	20	17	15	20	10	10	12	11:00
0500	11:00	15	20	15	15	20	10	10	15	12:00
0600	12:00	15	17	15	15	20	10	10	15	1:00
0700	1:00	17	20	15	17	20	10	12	15	2:00
0800	2:00	17	20	20	17	20	12	15	17	3:00
0900	3:00	20	20	15	17	20	12	15	20	4:00
1000	4:00	20	20	12	20	20	15	20	20	5:00
1100	5:00	20	15	12	20	20	15	17	20	6:00
1200	6:00	15	15	10	15	30	20	17	17	7:00
1300	7:00	15	15	10	12	30	15	20	15	8:00
1400	8:00	15	12	10	12	30	20	20	15	9:00
1500	9:00	12	12	10	10	30	17	20	15	10:00
1600	10:00	12	12	10	10	30	17	20	20	11:00
1700	11:00	10	10	10	10	30	17	20	30	12:00
1800	12:00	10	10	10	10	20	15	20	20	1:00
1800	1:00	12	10	12	10	15	12	10	15	2:00
2000	2:00	15	12	12	10	15	10	10	15	3:00
2100	3:00	15	12	12	10	12	10	10	15	4:00
2200	4:00	20	15	15	10	12	10	10	12	5:00
2300	5:00	20	15	15	10	12	10	10	12	6:00

EASTERN USA

GMT	EDT	N ASIA FAR EAST	NE EUROPE	E S. AFRICA	SE CARIBBEAN S. AMERICA	S ANTARCTICA	SW NEW ZEALAND	W OCEANIA AUSTRALIA	NW JAPAN
0000	8:00	12	15	15	10	17	10	10	10
0100	9:00	12	17	17	10	17	10	10	10
0200	10:00	15	17	17	12	20	10	10	12
0300	11:00	15	30	17	12	20	10	10	12
0400	12:00	17	20	20	15	20	10	10	15
0500	1:00	17	30	15	15	20	10	10	15
0600	2:00	20	20	15	15	20	12	10	17
0700	3:00	20	20	20	17	20	12	12	17
0800	4:00	17	17	15	17	20	12	15	20
0900	5:00	15	17	12	20	20	15	15	20
1000	6:00	15	15	12	15	20	20	20	17
1100	7:00	12	15	10	12	20	15	17	15
1200	8:00	12	15	10	12	30	15	17	15
1300	9:00	10	15	10	10	30	15	20	15
1400	10:00	10	12	10	10	30	17	20	15
1500	11:00	12	12	10	10	30	17	20	20
1600	12:00	12	12	10	10	30	17	20	20
1700	1:00	15	12*	10	10	20	12	20	17
1800	2:00	15	12	10	10	17	10	20	15
1800	3:00	17	12	12	10	15	10	10	15
2000	4:00	20	12	12	10	17	10	10	15
2100	5:00	20	12	12	10	12	10	10	15
2200	6:00	20	15	15	10	12	10	10	12
2300	7:00	17*	15	15	10	12	10	10	12

JUNE

Tom McMullen, W1SL



PART 1

VISUAL AIDS — OSCILLOSCOPES

One of the most useful aids for determining how electronic circuitry works or troubleshooting faulty equipment is something which can be used to examine the signals present at various points. Signals and waveforms weren't very complex early in the electrical age, and one instrument used to "look" at waveforms involved projecting a beam of light. This "oscillograph" device used a tiny mirror affixed to an armature. A narrow beam of light was focused on the mirror. When the armature was excited by a waveform the light beam reflected from the vibrating mirror would trace a pattern on a ground glass screen, a nearby wall, or photographic film. The frequency response of this system was limited by the mechanical inertia of the armature and mirror.

When waveforms became more complex (as with higher audio and low-range radio frequencies), the mechanical device was useless. The oscilloscope picked up where the oscillograph left off. The heart of the oscilloscope is the cathode-ray tube (CRT) which, in addition to being an excellent test instrument, is also the basis for many other essential inventions — including radar "scopes," television sets, and most computer screens.

The oscilloscope's principle of operation is amazingly similar to the mirror-type device — except that the moving part is not a mirror, but electrons with no inertia to hamper the faithful reproduction of waveforms. As shown in **Figure 1**, the CRT can present information along three axes.

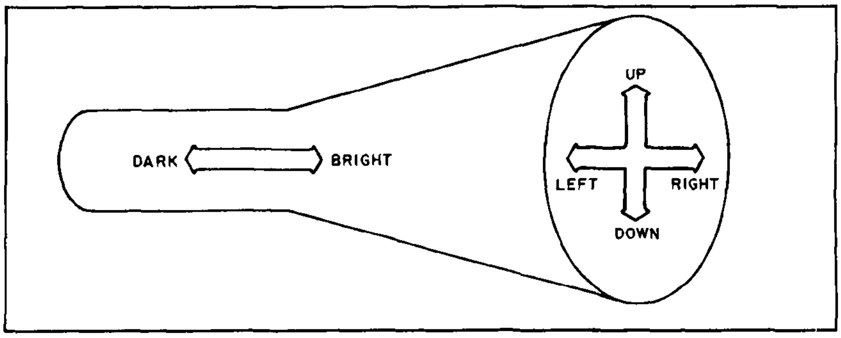
Before getting into a discussion about generating and deflecting the electron beam, I'd like to talk about how you can see the waveform on the front face (screen) of the tube even though the electron beam is invisible. The inside surface of the tube front is coated with a "phosphor" material which emits light when electrons strike it. At first the phosphor emitted only green light, and that was the standard color of oscilloscope traces for years. White phosphors were eventually perfected and used in early black-and-white television sets. Some specialized yellow screens were popular in early radar "scopes." Some of these phosphors would glow long after the electron beam had moved on to another spot. This characteristic is called "persistence;" it's beneficial in some uses and detrimental in others. The technique of using phosphors that would glow red, green, and blue was also developed. These phosphors were the precursors of present-day color television receivers and multi-color computer monitors.

The electron gun

No, it's not the latest arcade game; it's the device that starts electrons on their path toward the screen of the tube. The interior of the CRT is a vacuum, so electrons can be pulled off the surface of a heated cathode by the charge on a nearby electrode — just as they are in amplifier tubes used in other applications. One difference is that the first electrode has a small hole in it. While many electrons are pulled off the cathode and strike the electrode, others pass through the hole and continue toward the screen. The voltage on this first electrode (G1 in **Figure 2**) determines the intensity of the beam. Other electrodes (F1, F2, and F3 in **Figure 2**) accelerate and focus the beam of electrons so that it strikes the screen as a tiny spot. This whole assembly fits near the base, in the narrow neck of the tube, and is called the electron gun.

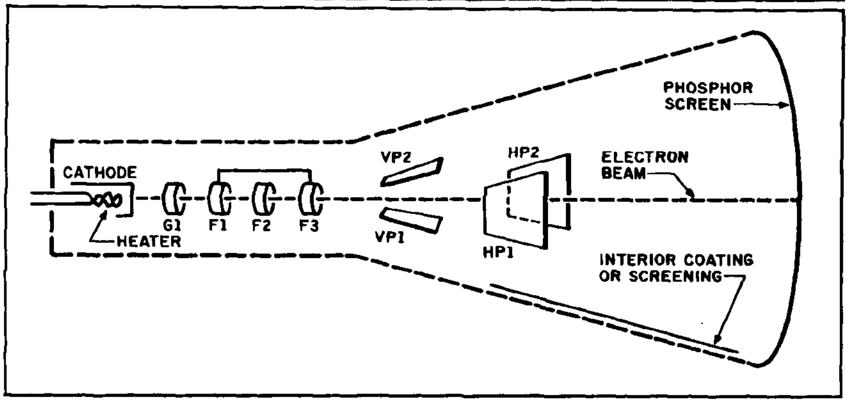
The glass shell of the tube flares out to support the screen of the CRT. This gives it a funnel-like shape. The inside surface of this flared part is usually coated with a conductive material connected to a high-voltage source of very low current capacity. This voltage keeps the electron beam tightly packed on its way to the screen and prevents electrons from "bouncing back" (secondary emission) when they hit the screen. Otherwise, stray electrons would distort the image. When used in an oscilloscope, the beam is almost always deflected by an electrostatic charge on the deflection plates, as shown in **Figure 2**. One pair of plates is mounted along the horizontal axis (HP1, HP2), and another pair along the vertical axis (VP1, VP2). For

FIGURE 1



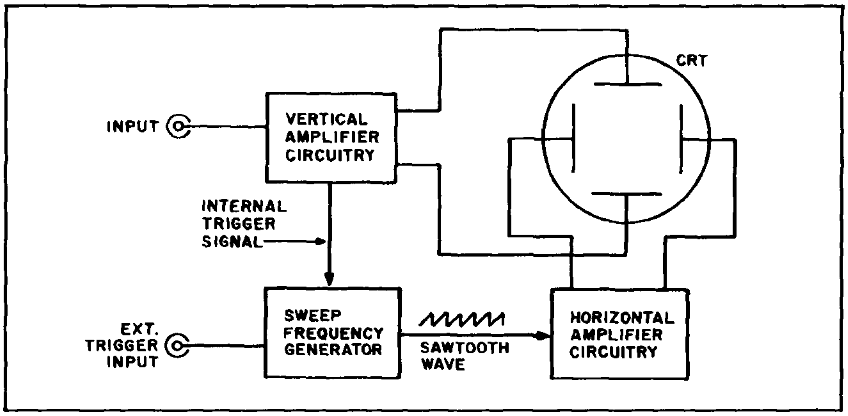
The usefulness of an oscilloscope is greatly determined by the cathode-ray tube (CRT) and its ability to show signals in two axes, vertical and horizontal. The third axis, bright and dark, enhances its utility as a test instrument.

FIGURE 2



The basic components of a CRT. It contains elements that change the intensity of the electron beam (G1), focus the beam (F1, F2, F3), deflect the beam (VP1, VP2, HP1, HP2), and help maintain the focus and intensity (the interior coating or screening).

FIGURE 3



The horizontal and vertical circuits needed to drive a CRT. The amplifiers are quite complex; they must amplify signals from DC to several MHz, and do so without distortion or a decrease in gain.

example, when a positive voltage is placed on the right plate and a negative voltage is placed on the left plate, the beam is deflected from left to right across the screen. The vertical plates function in the same manner. The signal from the vertical or horizontal amplifier circuitry is applied to the deflection plates 180 degrees out of phase, just as in a push-pull amplifier for audio or radio frequency use. This combination lets you control the position of the spot anywhere on the screen to trace even the most complex waveforms.

The third axis

An interesting new capability is added to the instrument when you start controlling a third variable — the brightness of the spot on the screen. By changing the voltage on the first electrode after the cathode (G1), you can control the intensity of the electron beam. You can make the spot brighter or dimmer, or extinguish it altogether. Turning the beam off is called blanking, and is useful in getting rid of "retrace" lines. To illustrate what this does for you, try a simple experiment. Grab a sheet of paper and a pencil. Place the point of the pencil near the left edge of the paper and move it to the right. Make the line wavy as you go, and stop just short of the right edge of the paper. Now, without lifting the pencil off the paper, move it directly back to the starting point. This last line is the retrace line, created when the electron beam returns to its starting point after each trace across the screen. By turning the beam off when it starts its retrace, you avoid making a distracting line across the waveform you're looking at. This blanking voltage can also be modulated with a series of square waves, allowing you to break the waveform on the screen into dotted or dashed lines as an aid in determining time duration (or frequency) of the signal. This is also how the light and dark areas of a television image are produced on the screen. The beam is modulated by a complex video waveform that reproduces the image formed in the TV camera.

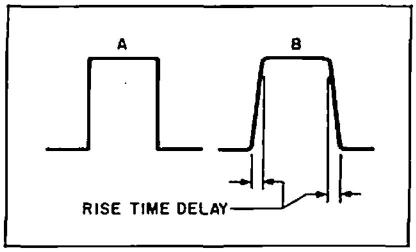
Electromagnetic (or just "magnetic") deflection of the electron beam is widely used in radar scopes and television receiver CRTs. Magnetic deflection has an interesting trait. The beam is deflected at right angles to the field between the coils. Therefore, the coils that deflect the beam right and left are mounted in a vertical plane. It's costly to mount electrostatic plates inside the tube and bring connections out through the glass wall. This is why television receivers universally use the relatively inexpensive electromagnetic deflection.

Other circuitry

A useful test instrument requires several circuits in addition to the basic CRT (see Figure 3). The voltage that deflects, or sweeps, the spot across the screen must be a waveform with a jagged shape like teeth on a saw — a sawtooth wave. Special oscillator and shaping circuits develop this waveform, and the frequency can be varied allowing different rates of sweep to look at a wide range of signal frequencies. The sweep can also be "triggered" on and off, allowing you to "catch" just one particular signal when it occurs. For example, perhaps you are looking at a 5 volts DC line, and want to see any noise or hum that rises to 5.5 volts. Set the trigger point to just below 5.5 volts, and any noise of that amplitude which appears on the line will cause the 'scope to start a trace and show the signal. This feature is often used when you take a photograph of the waveform on the screen. The trigger can be fired manually or automatically to produce just one sweep while the camera shutter is open.

An amplifier is usually required to boost any input signal up to a level that will deflect the beam vertically. This circuit, called a vertical amplifier or verti-

FIGURE 4



Distortion can be caused by poor vertical amplifier response. The original squarewave at A is degraded as shown at B. The poor response, also causes the corners to be rounded when the horizontal portion starts or stops.

cal deflection amplifier, requires a very special design. It must amplify signals that range from a very few Hz up to several MHz, do so with almost no distortion, and have equal gain over the entire range. (Some circuits actually pass DC voltages so you can measure the signal by deflection from a base line.) This is no small trick, and was very difficult to do with vacuum tube amplifiers. Solid-state devices seem to handle the task easily when coupled with appropriate impedance-matching and bandpass circuitry. A garden-variety oscilloscope should be able to pass 20 MHz; one that's useful to over 50 MHz isn't too hard to find at reasonable prices. While 'scopes of this range will suffice for troubleshooting most Amateur equipment, you'll need something rated to near 100 MHz if you want to look at the pulses in digital equipment like computers. Unfortunately, this kind of equipment is significantly more expensive.

The importance of this vertical response frequency can be seen in Figure 4. Figure 4A shows an actual square wave; 4B shows the wave as it might appear on an average oscilloscope screen. The reason it doesn't look square on the screen is because of something called vertical response time or rise-time delay. When the flat (+) part of the square wave stops, the beam descends toward the negative (–) part. However, the beam is still sweeping from left to right, so the spot doesn't land directly below the end of the + bar. The same thing happens when the – part stops and the beam rises to the + level. The time it takes to get from – to + (and vice versa) is called the rise time; the shorter that time is, the more like the true waveform the trace will be. How does this relate to frequency? A 100-MHz signal rises and falls 100 times faster than a 1-MHz signal. An amplifier with a rise-time response equal to 100 MHz will faithfully reproduce some pretty steep waveforms, while one that is only rated at 1 MHz will distort the waveform (see Figure 4B).

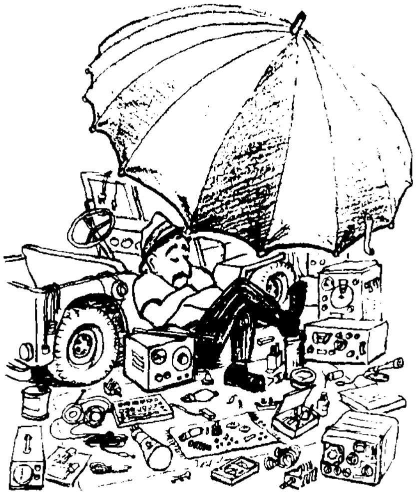
Some oscilloscopes incorporate a "Z" axis amplifier to control the brightness of the trace. This isn't often needed in general troubleshooting, but in some instances it can be used to impress external signals — like time markers (a bright "pip" every 100 milliseconds) or frequency markers (a pip every 1 MHz in a spectrum analyzer) — on the electron beam.

An oscilloscope requires various voltages for operation, and the power supply is accordingly complex. It must supply a range of positive voltages for the accelerating and focusing anodes, and for the brightness control. Positive voltage is required for the deflecting anodes, and a very high voltage is placed on the interior conductive coating. This voltage, sometimes called the "ultor anode" voltage, varies from near 2000 volts in common oscilloscopes up to 20,000 or 30,000 volts in some television receivers. The current is in microamperes and not directly lethal, but contact with it will usually cause severe muscle reaction which can result in physical injury.

As you can see, the oscilloscope is an extremely versatile instrument. A meter's pointer is a one-axis device which indicates amplitude, and that is exactly what the vertical axis of a CRT does. The horizontal sweep circuit in an oscilloscope introduces another axis which lets you look at a waveform over a specific period of time. The brightness control introduces a third axis that hides retrace lines, and lets you trace an image on the screen. In part 2, I'll look at another visual aid, the light-emitting diode (LED), and some of its uses.

For further reading:

If you'd like to learn more about the workings and uses of oscilloscopes, I recommend *Oscilloscopes*, by Rien van Erk, McGraw-Hill, 1978. It's an excellent, well-illustrated tutorial. hr



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ELECTRONIC COURSE, Heath ET-3100 w/lab $80. RF signal generator 90kc-240mc $50, Hickok 890 in-circuit transistor tester $45, RCA Voltohmyst VTVM $15. Want: Cushman CEj-3 plug-in's. K6KZT (805) 528-3181.

AEA CP-1 $50. Cetron 572B tubes, $65/pair. Yaesu NC-288 charger $9. 1989 NA Callbook $23.95. O. Heise, AA6EE, 16832 Whirlwind, Ramona, CA 92065. (619) 789-3674.

100 QSL CARDS $8. $3 thereafter. Grid square printed free. Shipped postpaid within two weeks. Guaranteed correct! Free samples. Shell Printing, KD9KW, Box 50B, Rockton, IL 61072.

YAESU FL-110 mobile linear. 10W in, 100W out. 160-10m. Like new $250. Janson, K6SHJ, 2027 Gillespie Street, Santa Barbara, CA 93101. (805) 681-2360, 682-5609.

HELP -need Collins 55G1 low freq preselctor for 51S1 receiver. F. Marx, 509-15 Court Street, Brooklyn, NY 11231. (718) 852-0765.

HAM SOFTWARE IBM/Compatibles. 10 disks $26.95 MC/VISA/Discover. N5ABV EAPCO, Keller, TX 76248-0014. (817) 498-4242.

R-390A RECEIVER parts: Info SASE. CPRC-26 military Manpack Radio, 6 meter FM, with antenna, crystal, handset: $22.50, $42.50/pair, radio-only $9.50. Military-spec TS-352 Voltohm/Multimeter, leads, info: $12.50. $4.50/piece shipping, $9 maximum. BAYTRONICS, Box 591, Sandusky, OH 44870.

WANTED: Old tube HiFi and studio components, loudspeakers, turntables, related magazines etc. Most makes and models, any condition. Jack Smith, 288 Winter Street, North Andover, MA 01845.(508) 686-7250.

UHF TEST EQUIPMENT: Hewlett-Packard TS403 (616B). UHF Signal Generator 1.8-4 GHZ $50. Jerrold VHF-UHF sweep generators $50.00. Tektronix 661 dual trace scopes (DC-3900 MHz!) no leads. $50. Avionics glide path and localizer sig. gen. $75 checked, $40 unchecked. AUL 1-7 GHZ sig. gen. $50. WW5B, POB 460, Brookshire, TX 77423.

POLICE/FIREFIGHTER HAMS - Please send your Call, Name, Address, Rank, Department Name, for inclusion in special roster available late 1989. Capt. Bob Blakeslee, N2IHO, 1-1/2 Macomber Ave, Binghamton, NY 13901.

WANTED: Ham equipment and other property. The Radio Club of Junior High School 22 NYC, Inc. is a nonprofit organization, granted 501(C) (3) status by the IRS, incorporated with the goal of using the theme of Ham Radio to further and enhance the education of young people nationwide. Your property donation or financial support would be greatly appreciated and acknowledged with a receipt for your tax deductible contribution. Get an incredible QSL for working our special event—June 26, 1100 to 2100 UTC, 7.238/21.395 MHz. Call WB2JKJ and the crew celebrating first day of summer vacation. Please write us at PO Box 1052, New York, NY 10002. Round the clock hotline: (516) 674-4072. Thank you!

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COMMODORE/AMIGA CHIPS (eg. 6510-$12.55, 6526-$13.50, 6567-$19.95, 6581-$14.85, 82S100-$15.75, 901 ROM Series-$12.50), PARTS, DIAGNOSTICS, HARD TO FIND ITEMS. Authorized service center. Fast REPAIRS, low cost (eg. C64-$49.95 plus UPS). Heavy duty power supplies for the C64-$27.95 plus UPS. Kasara Microsystems (Division of QEP), Route 9W/Kay Fries Drive, Stony Point, NY 10980, 1-800-248-2983 (outside NY) or 914-942-2252.

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R-290A Receiver Parts: Info SASE. CPRC-26 military Manpack Radio, 6 meter FM, with antenna, crystal, handset: $22.50, $42.50/pair. CPRC-26 Radio-only: $9.50. Add $4.50/piece shipping, $9 maximum. Baytronics, Box 591, Sandusky, OH 44870.

COMMUNICATIONS BATTERIES: Clone Packs! Ready-for-use. ICOM: BP-3S Double BP3 "Wall Chargeable" $43.95, BP5 $43.95, Yaesu: FNB2 $21.95, SANTEC 142/442/1200 (3 Pin) $23.95. "REbuilding—Send-Ur-Pack" ICOM BP3 $20, BP5 $28, BP7i/8 $34, Yaesu FNB4/4A $38, Kenwood PB21 $18, PB25/H/26 $28, T-T 2991 $29. "U-DOIT REPAIR INSERTS" ICOM: BP2 $18.95, BP3 $16.95, BP5 $23.95, BP7/BP8 $28.95, Kenwood: PB21 $12.95, PB24 $19.95, Azden 300 $19.95, Yaesu FNB4/4A $32.95, Tempo S1,2,4,5,15/450 $22.95, "ANTENNAS" 2Mtr 5/8-Tel/BNC $18.59. "MUCH MORE" SASE Catalog. PA +6%. $3 shipping/order. VISA-MC + $2. (814) 623-7000. CUNARD ASSOCIATES, Dept H, RD 6, Box 104, Bedford, PA 15522.

450 MHz SPECTRUM ANALYZER. Adapted from Nov 85 QST article by Al Helfrick, K2BLA. Use your low frequency scope for the display portion. Log output calibrated in 10 db steps. For complete kit, order #450-KIT $459.95 plus $4.50 s/h. Calif. residents add 6% sales tax. Foreign orders add 15% for shipping. For additional information send large SASE to: A & A ENGINEERING, 2521 W. LaPalma, #K, Anaheim, CA 92801 or call (714) 952-2114.

FOR SALE: Browning Golden Eagle Mark IV AM/SSB citizen's band receiver. Superb performance—tube-type double conversion, low noise, two tunable bands or crystal controlled. Use on CB, retune for 10 meters, or use as tunable IF for 2 meter, satellite or microwave receiver. Missing top cover, otherwise complete and working, with schematic. $100.00. Peter Ferrand, WB2QLL, 65 Atherton Avenue, Nashua, NH 03060. (603) 889-1067.

WANTED: All types of Electron Tubes. Call toll free 1-800-421-9397 or 1-612-429-9397. C & N Electronics, Harold Bramstedt, 6104 Egg Lake Road, Hugo, MN 55038.

SCHEMATICS. Devices, modules and components. Catalog $1.00 refundable. Free flyer LSASE. George Whitmore, 5746 Aberdeen Angus Way, Las Cruces, NM 88001.

N6SR/KX6: Anyone who has worked me as /KX6 has worked an illegal station. Anyone hearing that call please notify me and the FCC immediately.

WANTED: G.E. Mastr-Pro UHF 250 watt base station or amplifier with power supply or amplifier along. K8RUR, (313) 697-8888.

FOR SALE: IC-2AT 5/8 whip, rubber duck ant., mike, IC-BP4 battery pack, IC-DC1, two IC-BP3's with charger. $200. Martin Hanft, POB 199, Gilsum, NH 03448.

UHF PARTS. GaAs Fets, mmics, chip caps, feedthrus, teflon pcb, high Q trimmers. Moonbounce quality preamps. Electronic sequencer boards. Send SASE for complete list or call (313) 753-4581 evenings. MICROWAVE COMPONENTS, PO Box 1697, Taylor, MI 48180.

WANTED: Ten-Tec QRP transceivers. Signalizer audio amplifier S20/S30 RX-10 receiver. Modules MX1 TX1 AA1 Argonaut and power supply. Russ Olmsted, 608 West Thompson Lane, Murfreesboro, TN 37129. (615) 893-5344.

COMMODORE-128 PROGRAM available to track the Amateur Satellites. Uses Keperlian data supplied by NASA free. Tracks up to 8 satellites simultaneously. Program also supports printing schedules and predictions for satellites. Use it to track MIR and talk to the Cosmonauts. SATRAK128, $26.50 includes shipping. Other information on this or other programs for the C128, requires a business size SASE. Reid Bristor, WA4UPD, PO Box 0773, Melbourne, Florida 32936-0773.

WANT: 32S3 xmtr, 250TL and 304TL tubes. KF6WM, 45300 Royal, King City, CA 93930.

OXERS—CUSTOMIZED PRINTOUT of antenna headings calculated for your location. List includes over 650 worldwide locations. Send Lat/Long coordinates, name, callsign, check for $12.95 U.S. Brian Henderson, VE6ZS, 23 Deermoss Pl SE, Calgary, Alberta, Canada T2J 6P5. (403) 278-2084.

HANDICAPPED NOVICE needs HF equipment donated—anything please. KA3OUE, (412) 531-7443 anytime.

OFFICIAL MILITARY-TYPE ID TAGS. ("Dog Tags")!! Customized with your Call Letters, etc. 5 seventeen space lines. 20" nickel plated chain included. $4.29 postpaid. JPW ENTERPRISES, PO Box 353, Logan, Utah 84321.

MAGAZINES WANTED: "Microwave Systems News" (MSN), "RF Design", "PCIM (Power Conversion & Intelligent Motion)" and "QEX" (1980-present). Call collect 519-742-4594 (Ontario) after 6 PM Eastern time.

IMRA International Mission Radio Association helps missionaries. Equipment loaned. Weekday net, 14.280 MHz, 1-3 PM Eastern. Nine hundred Amateurs in 40 countries. Rev. Thomas Sable, S.J., University of Scranton, Scranton, PA 18510.

QUAD ANTENNAS 10-12-15 meters $139.95. 10-15-20 meters $199.95. Light weight fiberglass construction. Lightning Bolt Antennas, RD 2, Volant, PA 16156. (412) 530-7396.

"SOME UNPUBLISHED THEORIES and MORE for The Radio Amateur" by Lymansson. Includes RF wattmeter, monimatch, balun etc. From R.L. Plohl-Beeman, Publisher. $10 ppd. POB 70, Loogootee, IN 47553.

BACK ISSUES OF HAM RADIO. Have most issues from 1969 to 1974. Mint condition. $3.00 for single issues. WN0G, 319-377-3563.

HAM TRADER YELLOW SHEETS. In our 27th year. Buy, swap, sell ham radio gear. Published twice a month. Ads quickly circulate—no long wait for results. Send No. 10 SASE for sample copy. $13 for one year (24 issues). PO Box 2057, Glen Ellyn, IL 60138-2057 or PO Box 15142, Dept HR, Seattle, WA 98115.

VHF-UHF-SHF. Large SASE. West Coast VHFer, POB 685, Holbrook, AZ 86025.

CHASSIS & CABINET KITS. SASE. K3IWK, 5120 Harmony Grove Rd, Dover, PA 17315.

ANALOG AND RF CONSULTING for the San Francisco Bay area. Commercial and military circuits and systems. James Long, Ph.D., N6YB (408) 733-8329.

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RUBBER STAMPS: 3 lines $5.00 PPD. Send check or MO to G.L. Pierce, 5521 Birkdale Way, San Diego, CA 92117. SASE brings information.

COMING EVENTS

Activities — "Places to go . . ."

SPECIAL REQUEST TO ALL AMATEUR RADIO PUBLICITY COORDINATORS: PLEASE INDICATE IN YOUR ANNOUNCEMENTS WHETHER OR NOT YOUR HAMFEST LOCATION, CLASSES, EXAMS, MEETINGS, FLEA MARKETS, ETC, ARE WHEELCHAIR ACCESSIBLE. THIS INFORMATION WOULD BE GREATLY APPRECIATED BY OUR BROTHER/SISTER HAMS WITH LIMITED PHYSICAL ABILITY.

May 21: ILLINOIS: Hamfest sponsored by the Kankakee Area Radio Society, Will County Fairgrounds, Peotone. 8-3. For information write KARS c/o Frank DalCanton, KA9PWW, RR 1, Box 361, Chebanse, IL 60922. (815) 932-6703 after 4 PM or (815) 937-2452 before 4 PM CST.

June 3-4: WASHINGTON: Hamfest sponsored by the Apple City ARC, Rocky Reach Dam, 7 miles north of Wenatchee. For information and registration Bob Lathrop, 919 N. Woodward Drive, Wenatchee, WA 98801.

June 3: NEW HAMPSHIRE: The Hosstraders Flea Market is back at the Deerfield Fairgrounds. Admission $5 per person. Wheelchair accessible. Questions or map SASE to WA1IVB, RFD Box 57, West Baldwin, ME 04091.

June 4: NEW YORK: Hall of Science Hamfest, sponsored by the Hall of Science ARC, Hall of Science parking lot, Flushing Meadow Park, 47-01-111 Street, Queens. Starts 9 AM. For information Steve Greenbaum, WB2KDG (718) 898-5599 or Arnie Schiftman, WB2YXB (718) 343-0172.

June 4: PENNSYLVANIA: Firecracker Hamfest sponsored by the Harrisburg RAC, Bressler Picnic Grounds, Harrisburg. Starts 8 AM. Contact Dave Dormer, KC3MG. (717) 939-4957.

June 10: NORTH CAROLINA: 2nd annual Hamfest and Computer Electronics Fair sponsored by the Forsyth ARC, Dixie Classic Fairgrounds, Winston-Salem. 9 AM to 3 PM. For information contact Jim Rodgers, N1DRI, POB 11361, Winston-Salem, NC 27166. (919) 760-2493.

June 10: COLORADO: Superfest "XI", Larimer County Fairgrounds, South Railroad Avenue, Loveland. 8 AM to 4 PM.
June 11: ILLINOIS: 32nd annual Hamfest sponsored by the Six Meter Club of Chicago, Santa Fe Park, 91st and Wolf Road, Willow Springs. Ticket Chairman, Mike Corbett, K9ENZ, 606 South Fenton Ave, Romeoville, IL 60441.

June 11: ILLINOIS: The 60th anniversary of EGYPTIANFEST, sponsored by the Egyptian ARC, at the Clubhouse, RI3 at I-270, Granite City. Contact Egyptian ARC, PO Box 562, Granite City, IL 62040. (618) 931-1177 Thurs eves.

June 11: KENTUCKY: "Ham-O-Rama '89" sponsored by the Northern Kentucky ARC, Erlanger Lions Park. Gates open 8 AM. For more information or registration N4OEB, NKARC, POB 1062, Covington, KY 41012. (606) 331-3258.

June 11: OHIO: The Goodyear ARC's 22nd annual Hamfest and family picnic, Wingfoot Lake Park near Akron. Flea market 8 AM to 4 PM. For tickets or information William F. Dunn, W8IFM, 4730 Nottingham Lane, Stow, OH 44224. (216) 673-8502.

June 16-17: MINNESOTA: Amateur Fair '89. NEW LOCATION—Aldrich Arena, Maplewood. 6-10 PM. For information, tickets write Amateur Fair '89, PO Box 290131, Brooklyn Center, MN 55429. (612) 653-9999.

June 16: ALBERTA: Annual Picnic sponsored by the Central Alberta Radio League, Burbank Campsite. Contact P. Fitzgerald, VE6QT (403) 746-2621 or D. Miller, VE6XF, (403) 886-4883 2FM32
June 17: MICHIGAN: 14th annual Swap Shop sponsored by the Straits Area ARC, Petoskey. 8 AM to 1 PM. For information Irene, N8HBT (616) 539-8986 or Clark, KA8TIL (616) 582-6455.

June 17: NEW JERSEY: 18th annual Hamfest sponsored by the Raritan Valley Radio Club, Columbia Park, Dunellen. Starts 8 AM. For information Dave, KA2TSM (201) 763-4849 or John, WA2C (201) 968-5070.

June 18: WISCONSIN: Hamfest sponsored by the Central Wisconsin Radio Amateurs, Student Center, University of Wisconsin, Stevens Point campus. Starts 9 AM. Free admission. For information Art Wysocki, N9BCA, 3356 April Lane, Stevens Point, WI 54481. (715) 344-2984.

June 18: MICHIGAN: Monroe Hamfest sponsored by the Monroe County Radio Communications Association, Monroe County Fairgrounds. Handi parking. All buildings wheelchair accessible. For information Larry Lindner, KB8AIZ, 2001 Ida-Maybee Rd, Monroe, MI 48161. (313) 587-3663.

June 18: MARYLAND: Father's Day Hamfest sponsored by the Frederick ARC, Frederick County Fairgrounds. 8 AM to 4 PM. For information Dave Durkovic, N3BKD, 7128 Limestone Lane, Middletown, MD 21769.

June 18: CALIFORNIA: Santa Maria Radio Swapfest, Union Oil Co Newlove Picnic Grounds, just south of Santa Maria. Gates open 9 AM. Talk in 146.94. For information Hank Korczak, W6PME, 917 West Anthony Way, Lompoc, CA 93436. (805) 736-1761.

July 2: PENNSYLVANIA: Murgas ARC Hamfest, Ice-A-Rama, Coal Street Sports Complex, Wilkes-Barre. Starts 8 AM. Contact Mike Benish, K3SAE, Bx 214, RD #1, Pittston, PA 18643. (717) 338-6863.

July 8: WISCONSIN: Swapfest sponsored by the South Milwaukee ARC, American Legion Post 434, 9327 South Shepard Avenue, Oak Creek. 7 AM to 2 PM. For details South Milwaukee ARC, POB 102, South Milwaukee, WI 53172-0102.

July 8-9: INDIANA: 19th annual ARRL Division Convention and Hamfest, Marion County Fairgrounds, Indianapolis. Gates open 6 AM both days. For information (317) 356-4451.

July 9: PENNSYLVANIA: 4th annual Hamfest sponsored by the North Hills ARC, Northland Public Library, 300 Cumberland Road, Pittsburgh. 8 AM to 4 PM. For information SASE to Bob Ferrey, Jr, N3DOK, 9821 Presidential Drive, Allison Park, PA 15101. (412) 367-2393.

October 1: NORTH CAROLINA: JARSFEST '89, Benson American Legion Complex, 301 N. Benson NC 27504. 8 AM to 4 PM. For flyer SASE to Johnston Amateur Radio Society, PO Box 1154, Smithfield, NC 27577. (919) 934-0486, 894-5479.

OPERATING EVENTS

"Things to do . . ."

June 9: The East Pasco Amateur Society will operate a special event station AB4LN to celebrate the centennial of Dade City, Florida. Operation starts daily at 10 AM. Send QSL and business SASE for certificate to EPARS Centennial, AB4LN, PO Box 942, Dade City, FL 34297-0942.

June 10: The Tusco ARC, New Philadelphia, Ohio, will operate W8ZX 1700 UTC from New Towne mall to celebrate the 50th anniversary of the club and to promote public interest in Amateur Radio. For QSL SASE to W8ZX, PO Box 725, New Philadelphia, OH 44663.

June 17: Chicago. The Amoco ARC will operate special event station W9GT from 1300Z June 17 to 0100Z June 18 to commemorate the 100th anniversary of the incorporation of Amoco Corp. Phone, CW and packet 80-10m and VHF. For special QSL SASE to Amoco ARC, Mail Code 0802, 200 E. Randolph Drive, Chicago, IL 60601.

June 17: The Prince Georges Amateur Radio Emergency Service, Maryland, will operate a special event station at the Prince Georges Worldfest. 1500 UTC June 17 to 0200 UTC June 18. This year marks the 293rd anniversary of Prince Georges County. For a special QSL card send QSL card and SASE to PG-ARES, PG EOP, 7911 Anchor Street, Landover, MD 20785.

June 18: 1989 SMIRK Party Contest. 0000 UTC June 18—2400 UTC June 19. Send contest entries by July 6, 1989 to Lisa Lowell, KA0NNO, PO Box 547, Hugo, CO 80821.

July 1: Colorado Six Meter Invitational Net is sponsoring an activity day contest. Exchange callsign, name, grid square and SIN number on 50 MHz. Send logs by July 31 to N0AKI, 8529 Fenton St, Arvada, CO 80003. Please SASE.

July 4: High Plains ARC will operate KT7V at historic Fort Laramie from 0000Z July 4 to 0000Z July 5. For QSL send business SASE to KT7V, 111 Camino Del Rey, Torrington, WY 82240.

LAUREL ARC *monthly (except December) Amateur exam sessions for all license classes. No fee is charged. Pre-registration is required. Call (301) 725-1212, Maryland Radio Center, 8576 Laureldale Drive, Laurel, MD 20707.*

NORTH COAST ARC 1989 LICENSE EXAMS. 12:30 PM, Saturdays February 11, April 15, June 10, August 12, October 14, December 9. N. Olmsted Community Cabin, S of Lorain on W. Park. Novice thru Extra. Walkins allowed. Talk in 145.29 repeater. For information Dan Sarama, KB8A, 15591 Rademaker Blvd, Brookpark, Ohio 44142. 267-5083 or Pauline Wells, KA8FOE, Rick Wells, K8SCI, 777-9460/779-8999.

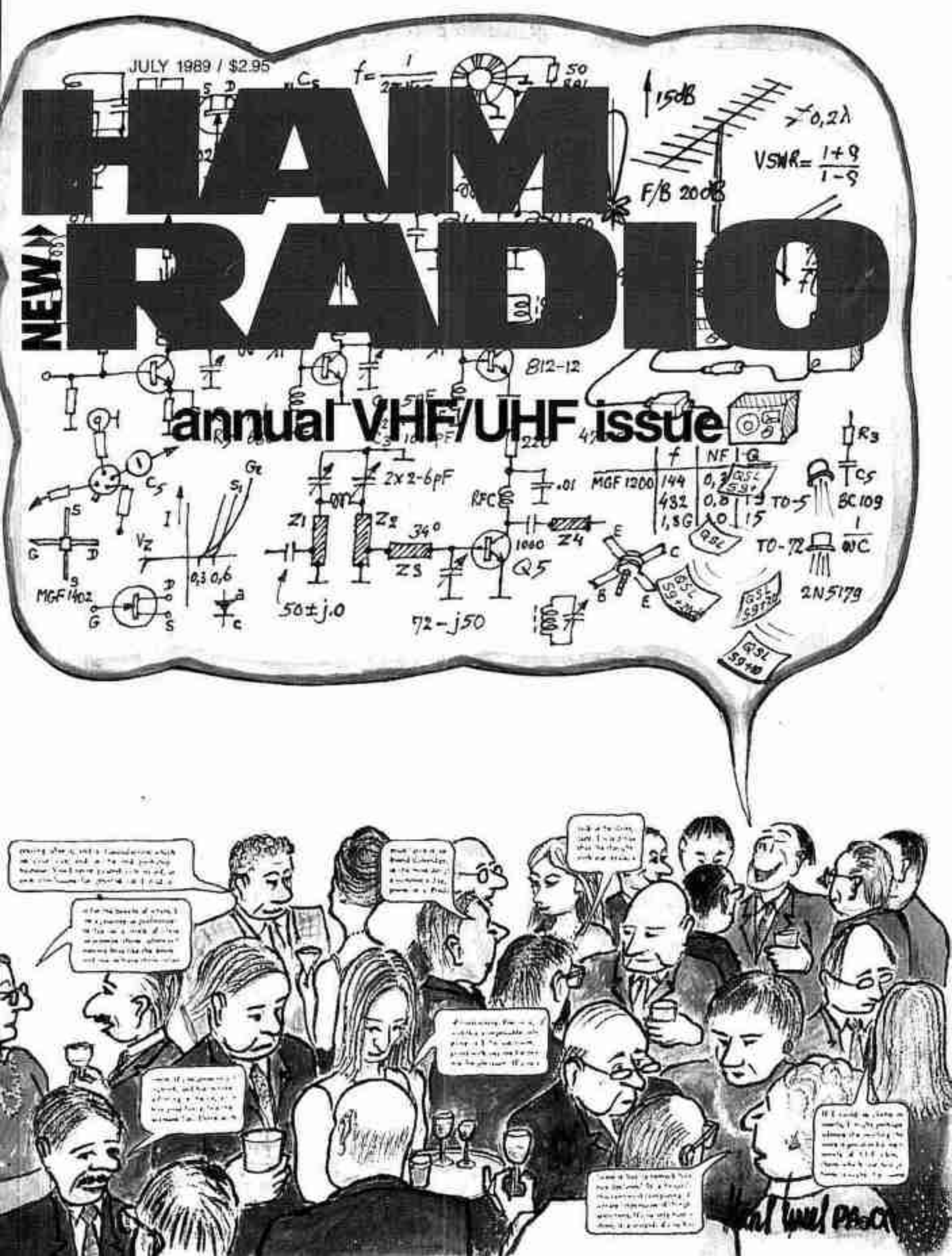
AMATEUR RADIO CLASSES: For those people interested in obtaining a Novice (basic level) Ham license or upgrading to Tech/General, the Chelsea Civil Defense, in cooperation with QRA Radio Club, will sponsor Amateur Radio Communications classes evenings at Chelsea High School starting MARCH 7, 1989. For more information write Frank Masucci, K1BPN, 136 Grove Street, Chelsea, MA 02150. Please enclose your telephone number.

THE MIT UHF REPEATER ASSOCIATION and the MIT Radio Society offer monthly HAM EXAMS. All classes Novice to Extra. Wednesday, JUNE 21, 7 PM, MIT Room 1-150, 77 Mass Avenue, Cambridge, MA. Reservations requested 2 days in advance. Contact Ron Hoffmann at (617) 484-2098. Exam fee $4.50. Bring a copy of your current license (if any), two forms of picture ID, and a completed form 610 available from the FCC in Quincy, MA (617) 770-4023.

JULY 1989 / $2.95

NEW HAM RADIO

annual VHF/UHF issue



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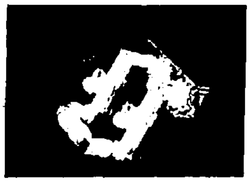
JULY 1989
Volume 22, Number 7



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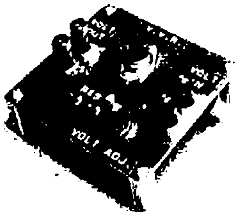

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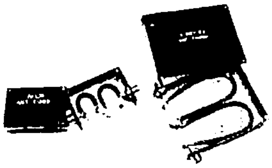

NH6N, page 84

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FEATURES

DEPARTMENTS

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Backscatter

The more things change, the more they remain the same

Sometimes, I get the feeling that Amateur Radio is going to explode into open warfare. No, I'm not talking about IARU societies fighting each other. But in certain aspects of the service, lawsuits, accusations, and innuendo seem to be the order of the day. Whatever happened to talking, reason, and the subtle art of negotiation?

Two repeater wars are brewing — one between a repeater group in Los Angeles, California and a group in Mexico. The other is between repeater groups in Illinois and Indiana. While I don't know if the group in the Southwest tried to arbitrate a solution to their problem, I am sorry to see that they chose the route of litigation in an attempt to solve it. According to *Westlink*, both repeaters have been coordinated by their local authorities onto the same frequency pair. I wonder if there was any communications between the two coordinating groups before the frequency assignment. I'd like to think there was. If not, we have slipped one step closer to spectrum anarchy. In the Midwest, a similar situation exists. With luck a solution can be negotiated between the coordinators and repeater owners so that they don't have to resort to litigation.

A glimmer of hope

But despite all the repeater troubles, there is a movement afoot which could help us cast off the chains of the past and move forward to a revitalized interest in Amateur Radio. I'm referring to the on-going discussions about no-code. (I would much rather call the new license class code-free or beginner's class, as I'm afraid no-code presents a negative image to some within the hobby.) *CQ*'s recent survey of their readership showed a 60-40% split in favor of a code-free beginner's license. As I reported last month, our informal sampling resulted in an even split. The ARRL's study committee has even suggested a code-less license to the ARRL Board of Directors with some very intiguing privileges. And even though some clubs and groups are vehemently against the idea, many others embrace it with open arms.

Marty, NB1H, and I gave a presentation to the Granite State Amateur Radio Club on the code-free license this past May. Most of the group looked on the idea favorably. Several, however, did not. Among other things, their biggest concern was control — would this new class of license open the floodgates to bad habits and other potential problems. On the drive home, I thought about their objections; I find that I do not agree with them. The code-free license is more than an attempt to reach out to those who simply do not want to learn the code. It is a effort to bring licensing into the 1980s with a ticket designed for a communicator. These hams will not be any less than those now currently licensed. It will be incumbent on us to get them to upgrade and gain more privileges. What will be the eventual outcome of the proposal? No one knows and it will be months before we have any idea.

So, the more things change, the more they remain the same! I sure hope we can find a way to mediate our differences and, at the same time, accentuate the positive things that are happening in our hobby. What we do not need is more litigation between Amateurs. In this era of government deregulation, the FCC simply is not going to be the "all powerful, omnipotent Oz" it used to be. Funds and personnel have been cut in the FCC offices to the bare bones. One communications lawyer commented to me that FCC regulation and operation were being done through "mirrors and tricks" — illusion in fact! We simply cannot depend upon the FCC to solve our problems. It is up to us to solve them for ourselves.

Can we do it? Can we police and maintain order in the Amateur service? I don't know, but I hope so. As long as the trend is toward asking the courts to solve our problems, we cannot. If we go back to arbitration amongst ourselves and depend on each other to deal in good faith, maybe it is possible. We'll see.

Craig Clark, N1ACH

Comments

Need for new challenges

Dear HR

Many of the ham magazines have recently featured letters or editorials which bemoan the slow or even negative growth in our numbers. Some press for some sort of "no-code" license as a panacea, guaranteed to reverse all of the undesirable trends and to rejuvenate the hobby.

What sort of growth would satisfy a manufacturer of ham gear or a publisher of Amateur Radio magazines? At the beginning of World War II, the ham population totalled about 50,000. The latest total I have heard is around 250,000. This five-times increase, which occurred during a period of time when our total population approximately doubled, seems a remarkable growth to me.

I am surprised however, that we retain as many in the hobby as we do. I have many memories of young children leaving sophisticated toys in the closet while spending long hours with crude, self-made ones. Could this same psycological mechanism be at work among hams who have tired of their complex toys? Where is the challenge in a hobby if the required license can be obtained by memorizing a few pages of data — and when sophisticated gear, beyond the understanding of most operators, is cheaply available? I can easily see why the excitement and the near magic I felt when I first became a ham does not exist for a big segment of our present group.

No one tried to encourage me in the mid-30s when I developed an interest in Amateur Radio and decided to get my license. I studied hard to understand the theory and copied code for long hours to get my speed up to 15 wpm or so. Then, I had to build homebrew gear as I could not afford commercial equipment. Every step along the way to getting on the air presented a challenge to a young teenager. I suspect it was the challenge that initiated and sustained my resolve.

What are the current challenges, technical or otherwise, that would entice newcomers to our hobby? Just acquiring the legal right to communicate with ham gear is not enough. Most publishers and even the ARRL appear to promote more and more sophistication in our equipment, but then sponsor increasingly simple activities in which to use it. Just learning a new computer program so that you can use your PC on packet requires little or no technical skill and is not much of a challenge. Occasionally I read or hear a derogatory remark about the simplicity of the homebrew gear so strong in the memories of those who were hams prior to WW2. I have but one response: The gear we built was near state-of-the-art for the times. How much homebrew gear is around today that you could consider state-of-the-art?

The early enchantment with the mysteries and complexities of the hobby does appear to be slipping away and cannot be restored by producing a mass of appliance operators. If up-to-date technical challenges cannot be initiated, I am afraid that our hobby will slowly be downgraded to a CB-type of activity, we'll hear more and more stations "backing-out" of QSOs, and blown fuses will soon become major problems.

Paul Swearingen, W9PJF,
Benton, Illinois 62812

Here we go again!

Dear HR

Well, the long suffering public (especially the Amateur Radio community) has been had again. The Feds have laid another bundle of fallacious logic on our heads and again expect us to bow down and take it.

The incising of the 220-222 MHz portion of the electromagnetic spectrum was again performed "in the public interest." Somehow I am sharply reminded of a child receiving a beating "for his own good." Oh, yeah? Really? Is THAT logical? "For his own good" indeed! Have you ever heard of anyone running up and asking for a beating "for his own good?"

Another one that goes right along with this is, "This is going to hurt me more than it will you." Oh, yeah? Then let ME do it to YOU — then it won't hurt you so much. I might admire a little more honesty in all of this. "I am going to beat you as a punishment for" or "I am going to beat you because I am bigger and stronger and have more power than you." At least you would know just where you stood in the grand schematic of things.

If we are going to play the numbers game with the FCC chief engineer (and treat ALL frequencies alike) and the land mobile service needs 2 MHz, then why not give them 2 MHz up at 24,000 MHz? That would amount to the same 2 percent that he claims is all that we are losing.

What is the fierce pressure to force a breakthrough in land mobile communications? Will those brown UPS trucks get the goods to your door appreciably faster? It would be most interesting to find out whose brother-in-law has a warehouse FULL of this new, breakthrough 220 mobile equipment — already. Or to unearth which country is ready to load ships full of this new, breakthrough stuff.

Remember that business (and politics) function just like the King — who always announces that he CAN TOO put Humpty Dumpty back together again. ALL HE NEEDS IS MORE HORSES AND MORE MEN!

Joseph A. Weite, KH6GDR,
Makakilo, Hawaii 96706

A 435-MHz LOW-NOISE GaAsFET PREAMPLIFIER

Upgrade your 435-MHz receiving system for OSCAR and terrestrial weak signal reception

Paul Gregory, WA2FTK, 136 Covered Wagon Trail, W. Henrietta, New York 14586 with Vic Gauvin, K1JUL, 27 Van Cortland Drive, Pittsford, New York 14534

Articles on VHF/UHF GaAsFET preamplifier construction aren't unusual. But many feel that these preamps are too difficult to build, that they are too unstable, or that parts are too hard to get. I hope my project will help to allay some of these fears.

Why a preamplifier?

Why add a preamplifier to your receiving system in the first place? Under extremely weak signal conditions (like those from a satellite), your receiving system needs all the help it can get. Things like feedline loss between the antenna and the receiver degrade the signal strength seen at the receiver's front end. In addition, the receiver may not be sensitive enough to hear the weak satellite signals. To overcome these problems you can add a low-noise preamplifier, like a GaAsFET, to the receiving system to improve overall receiving system performance.

Let's look at the satellite downlink receiving system at my station. I have 65 feet of 9086 coax (similar to 9913) between the antenna and a 435-MHz receiver. The cable loss is approximately 3.1 dB per 100 feet, which is 2 dB for 65 feet at 435 MHz. The receiver's RF amplifier has 10 dB of gain with a noise figure of 5 dB — not a very sensitive system. With a typical satellite signal level at the antenna terminals, the receiving system performance can be illustrated by the signal-to-noise (S/N) ratio at the receiver input to the mixer. This is shown in **Figure 1** (see appendix A at the end of the article for assumptions and computations). As is the case with any system, the losses and noise contributed by the system components degrade the S/N ratio at each step in the signal path. Because of the low signal levels in this case, the contribution is significant and greatly degrades the signal by the time it reaches the receiver mixer. There's 4 dB of S/N reduction due to the coax and 7 dB at the receiver — a net S/N ratio of 6 dB. It's necessary to increase the working signal to levels much higher than the noise, so that the noise has less effect.

Where to add a preamp?

The addition of a preamplifier at the receiver input is a common solution to this problem. **Figure 2** shows what happens when you add the 20-dB low-noise amplifier discussed later in this article. The 4-dB S/N degradation resulting from the coax is still present, and you have an additional degradation of 1 dB due to the preamp itself. However, the noise contribution caused by the receiver has been reduced to approximately 0.1 dB, as compared with the 7 dB of the previous system. This is a 6-dB net improvement in S/N for a final ratio of 12 dB. For a greater improvement, increase the working signal level at the coax to the point where the coax noise is insignificant with respect to the signal level — just as you did with the receiver noise.

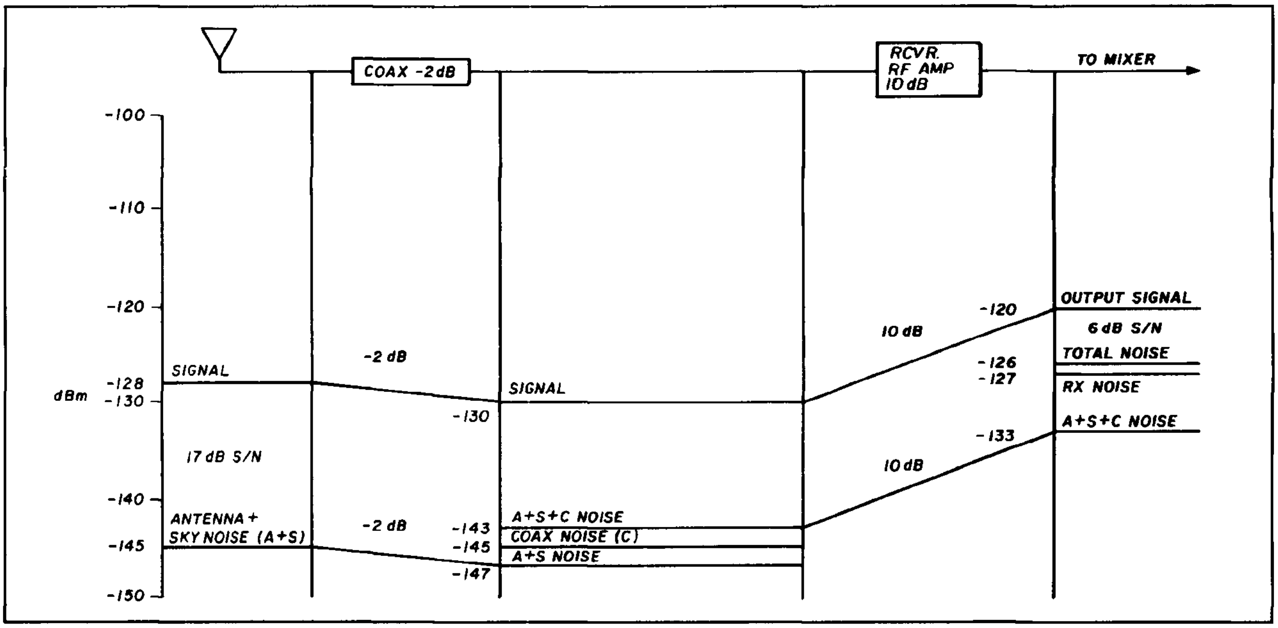
To do this, you must amplify the input signal at the antenna before it reaches the coax. The results of this configuration are illustrated in **Figure 3**. As you can see, the preamp S/N degradation is now roughly 0.6 dB and the coax contribution changes from 4 dB to 0.1 dB! The receiver contribution is still insignificant at 0.3 dB and the net S/N is now 16 dB, nearly as good as it is at the antenna.

As these examples show, it's not how much gain your amplifiers have (the final signal level in **Figures 2** and **3** is the same), but where in the circuit the gain occurs that determines your ability to increase the signal above the noise to a point where you can reduce its effect significantly.

The preamp

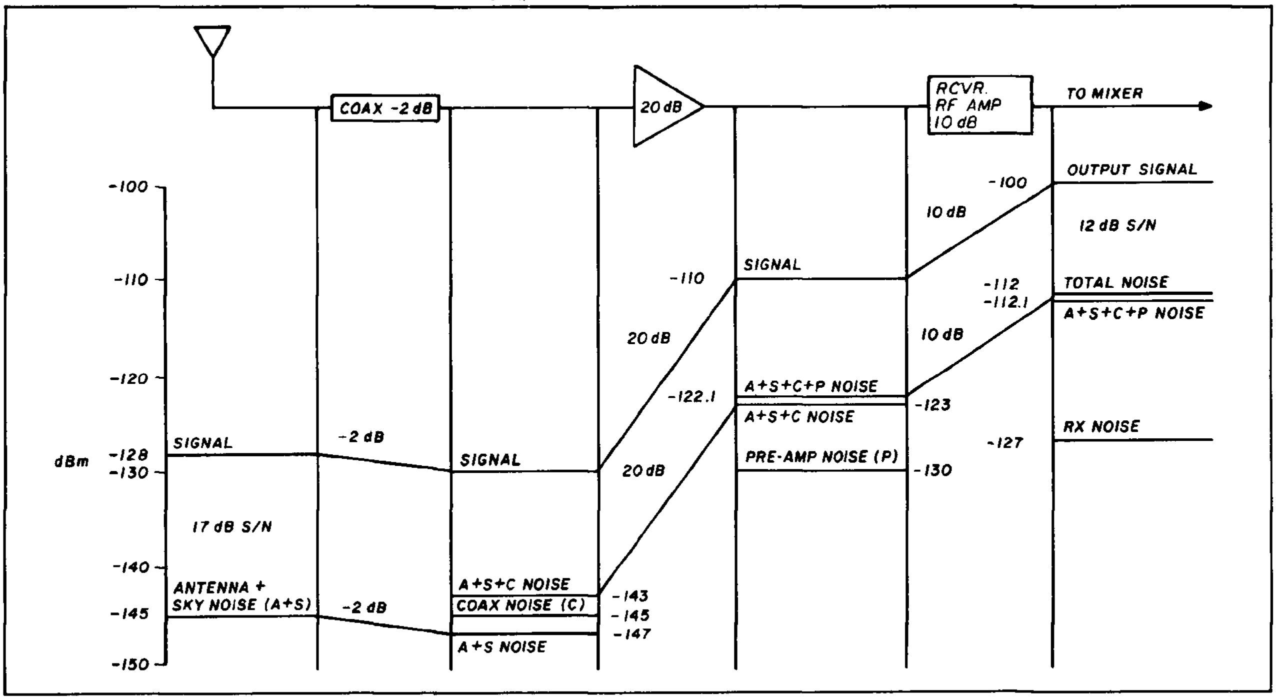
The GaAsFET preamplifier circuit I've described here is similar to one in *The ARRL Handbook*[1]. I made minor changes to improve stability and allow operation at 28 volts DC because of my relay requirements. It offers excellent

FIGURE 1



S/N calculations — no preamplifier.

FIGURE 2



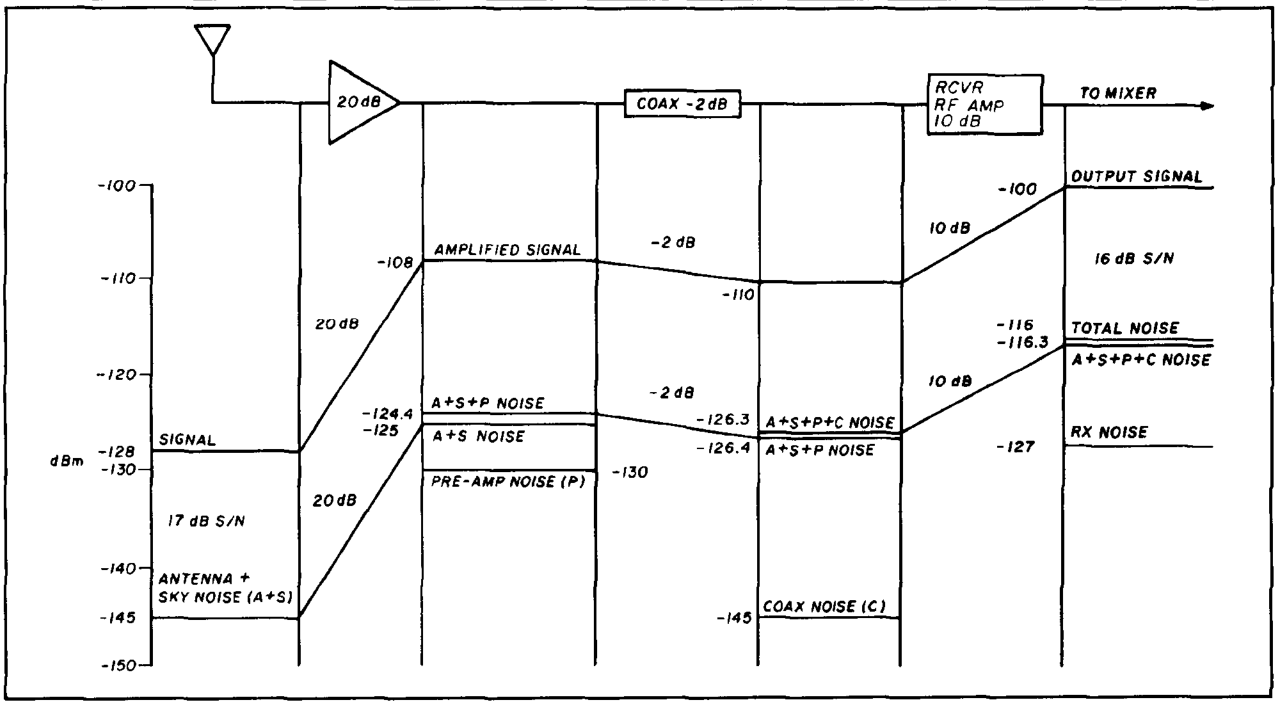
S/N calculations — preamplifier at receiver input.

performance and gain, and can be used for both satellite and terrestrial communications.

Circuit details

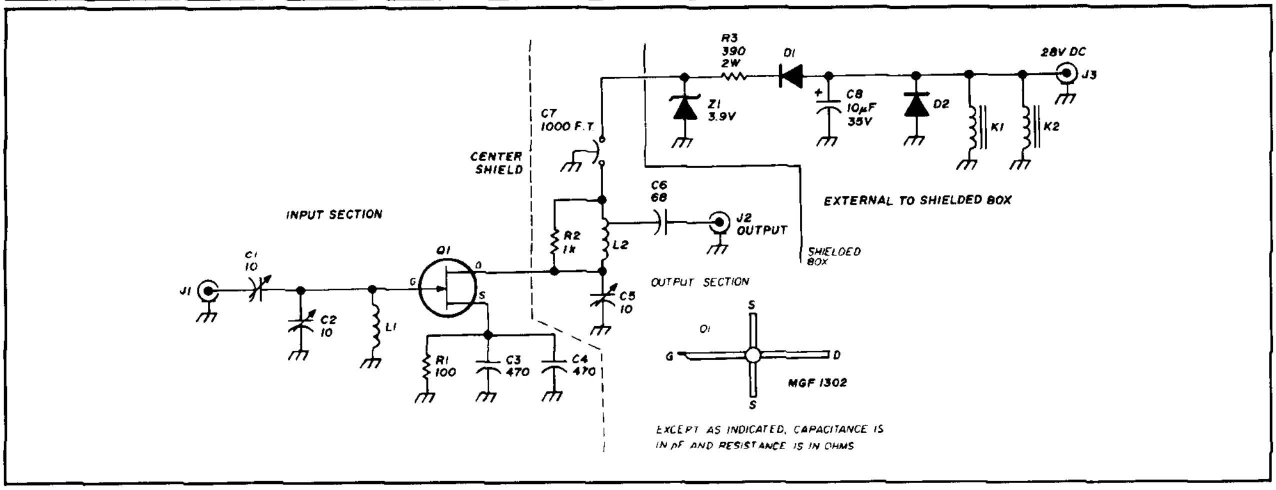
The basic circuit is shown in **Figure 4**. The GaAsFET transistor is a Mitsubishi MGF 1302, which provides approximately 18 to 20 dB of gain in this circuit. The input is tuned by C1, C2, and L1; the output is tuned by C5 and L2. You can use miniature ceramic trimmer capacitors for the variable capacitors; however, I recommend piston-type capa-

FIGURE 3



S/N calculations — preamplifier at antenna.

FIGURE 4



Schematic diagram. Except as indicated, values of capacitors are in pF. Resistances are in ohms.

citors. The source bypass capacitors, C3 and C4, are leadless trapezoidal capacitors. Note that there are two source leads on the GaAsFET transistor, and that each lead is connected to a trapezoidal bypass capacitor. The output coupling capacitor, C6, is a silver mica.

The relays I used require 28 volts DC, so the preamplifier circuit is designed to work at that voltage. If you use 12-volt relays instead, change R3 from 390 ohms to 150 ohms, 2 watts.

When DC voltage is not applied to the amplifier circuits, the preamp is in transmit mode, bypassing the amplifier (see **Figure 5**) and protecting the GaAsFET from static charges when not in use.

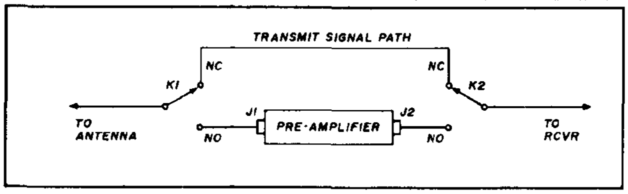
Construction details

I built the complete amplifier circuit on a piece of double-sided pc board 3-3/4" × 1-5/8". The remaining sides are double-sided pc board soldered together. The long sides

PARTS LIST

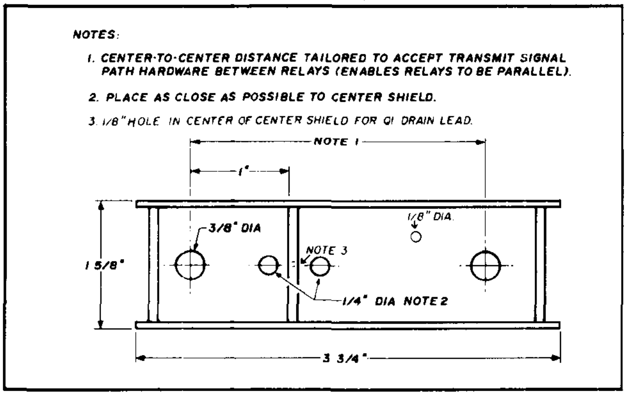
C1,C2,C5	0.8 to 10-pF piston trimmer, Johanson or Trimtronics
C3,C4	470-pF leadless trapezoidal
C6	68-pF silver mica
C7	1000-pF solder-in feedthrough
C8	10-μF, 35-volts DC electrolytic
D1,D2	1N4004
J1,J2	BNC chassis mount
J3	F connector, Radio Shack 278-212
K1,K2	Relay, Amphenol 300-11361 (shorting type)
L1	2.5 turns 3/16-inch inside diameter, 1/4 inch long, 22 AWG
L2	2 turns 3/16-inch inside diameter, 22 AWG, tapped 1/2 turn from C7 end, turns spaced 2 wire diameters
Q1	Mitsubishi MGF 1302
R1	100-ohm, 1/4-watt metal film
R2	1-k, 1/4-watt metal film
R3	390-ohm, 2-watt carbon composition
Z1	1N4730, 3.9 volts, 1 watt
	Enclosure approximately 4 x 5 x 6 inches

FIGURE 5



Normally closed position of antenna switching relays is used to bypass the preamplifier for protection from atmospheric static charges. A shorting-type relay is used to short the open contacts to ground during transmit, therefore providing further protection from RF leakage.

FIGURE 6



Shielded box dimensions. Note 1: Center-to-center distance tailored to accept transmit signal path hardware between relays (enables relays to be parallel). Note 2: Place as close as possible to center shield.

are 3-3/4" × 1", and the two end pieces are sized to fit. Refer to Figure 6 for dimensions and hole locations. Make sure the solder joining the sides is continuous along the board edges, both inside and outside the enclosure. (Tack solder all the sides first to be sure everything fits properly.)

Before you install the center shield, drill a 1/8" hole in its center and solder one 470-pF trapezoidal capacitor (C3 and C4) to each side of the hole.

Figure 7 shows a suggested component layout diagram. Install J1, C2, C5, C7, and J2, as well as C3 and C4 on the center shield, first; they're used as mounting points for other components. You may wind L1 and L2 on a 3/16" drill bit. The direction of the turns isn't important, but you should wind the input and output inductors in opposite directions. This will help to minimize coupling. Make your lead lengths as short as possible. I did this for L2 and R2 by placing the resistor inside the coil and soldering to a common point.

To protect the GaAsFET, I suggest that you install it last (along with R1). Place the drain of the GaAsFET (the longest lead) through the hole in the center shield and solder each source lead to the trapezoids (see **Figure 7**). Use care when handling the GaAsFET: discharge yourself by touching a grounded metal object before handling the transistor. It is static sensitive and may be damaged if you don't. Also, when soldering the leads, be sure not to use excessive heat. Be sure the drain lead is centered in the hole after you've soldered the two source leads.

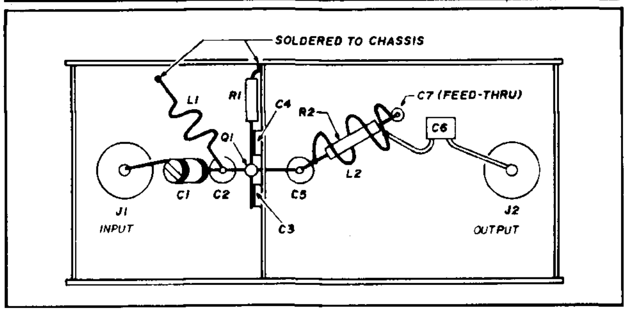
Note that Z1, D1, D2, R3, and C8 are located outside the shielded box. D2 and C8, as well as K1 and K2, are connected at J3, the DC input connector at the enclosure that houses the entire assembly. D1 and R3 are in series to feedthrough capacitor C7 at the shielded box. Z1 is connected to C7 and grounded right to the outside of the box.

The shielded box is designed to connect to the coaxial relays (see **Photo A**). Each relay contains two bulkhead-mount N connectors, with O rings on one side for weatherproof mounting and a BNC male connector on the other side. The preamplifier connects directly to these BNCs and is supported by the relays. Attaching the relays to a weathertight chassis provides a convenient method of installation; everything is held in place by the mounting hardware (**Photo B**).

The transmit signal path connection between the relays is made up of two 90° elbow N connectors and the double-male N.

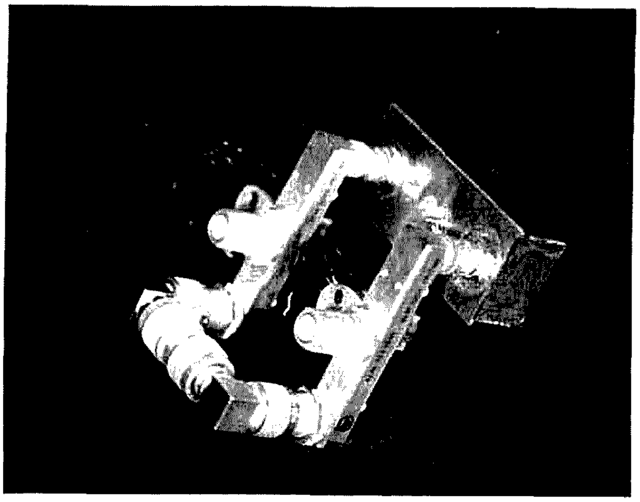
The final assembly (before weatherproofing) is illustrated in **Photo C**. I used an F connector for the DC input (J3) because I needed shielded cable (like RG-59) to protect the preamp from atmospheric static while not in use. The enclosure should also be grounded to the antenna tower.

FIGURE 7



Suggested component layout. All leads must be as short as possible (use C6 to make up the distance required to J2 because of relay spacing).

PHOTO A



The shielded assembly connects directly to the transmit/receive relays. The photo illustrates the hardware used for the transmit signal path (used whenever preamplifier is not in operation).

Tuneup

You can do the initial amplifier tuneup before you connect it to the relays and install it in the receive line. Be sure that the transmitter cannot be keyed. Tune in a known signal strong enough to just move the S-meter and adjust C2 and C5 for maximum S-meter reading; then tune C1 for best signal-to-noise ratio. Retune C1 and C2 for best signal-to-noise and maximum gain as necessary. Disconnect the antenna; the background noise should be greatly reduced.

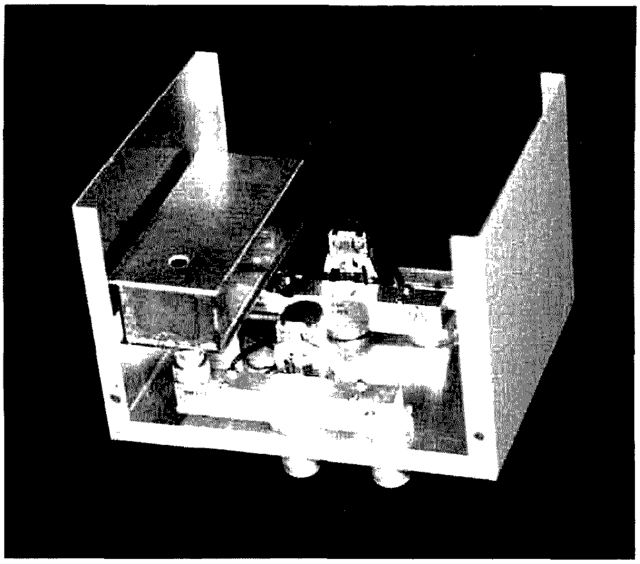
Tune around the band to determine if there are any "birdies" caused by the amplifier. If there are, adjust C5 until they disappear. *Do not touch C1 and C2.* (Since I added R2, I've encountered no difficulties in this configuration. If you do have problems, refer to the December 1987 *Ham Radio* "VHF/UHF World" column by Joe Reisert, W1JR.) Reconnect the antenna and you'll find that the background noise reappears. Readjusting C5 will slightly detune the output stage; however, sufficient gain in the circuit means that gain reduction will be insignificant.

Parts information

Components C1-C5, C7, and Q1 are available from:
Microwave Components of Michigan
11216 Cape Cod
Taylor, Michigan 48180

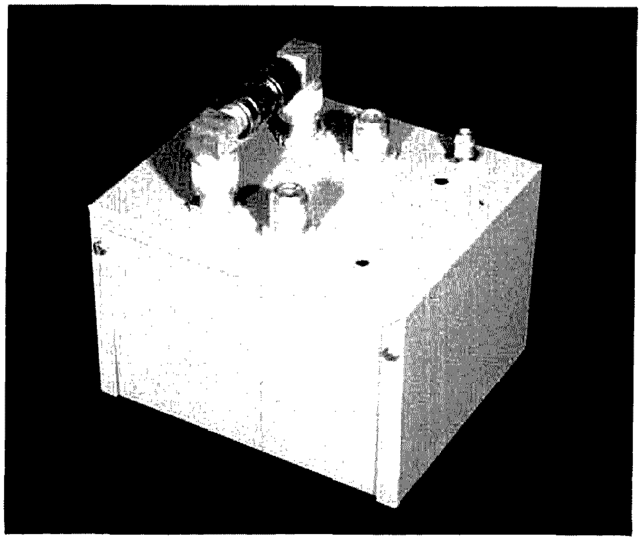
I purchased the relays at a hamfest. They are manufactured by Amphenol, and provide the minimum number of external adapters to connect to the preamplifier without requiring a custom relay. You can use any high quality coaxial relay provided it can handle the power requirements of the transmitter, provides enough isolation during transmit to protect the preamplifier, and is rated to at least 500 MHz. Relay substitution may require additional adapters to interface to the preamplifier and external coax to the antenna and the station.

PHOTO B



The entire assembly mounted in its enclosure. The hole in the shielded box is an optional access hole for adjustment of C1. The "power-related" components attach to J3 at the enclosure (hidden under the shielded box), keeping them out of the RF section of the circuit.

PHOTO C



Final assembly in its enclosure before weatherproofing. The antenna and feedline to the receiver connect at the N connectors. The F connector is the input for the shielded power cable.

Conclusion

Adding this amplifier to your station will give you a state-of-the-art receiving system for modes J and L operation, as well as significantly improved terrestrial operation. You'll really be able to hear those weak signals and enjoy satellite/UHF DXing. hr

REFERENCE

1. "GaAsFET Preamplifiers for 144 and 220 MHz," *The ARRL Handbook for the Radio Amateur*, ARRL, 1986 and later editions.

Appendix A

Computations and assumptions

The values used in the signal-to-noise ratio diagrams are based on typical signal levels in "average" station setups. Values are given in dBm since most people can relate to these by way of other experience. All values in the illustrations have been rounded, and some "adjusted" by no more than a few tenths to simplify the diagrams. The following is the basis for several of the values used.

Input signal level (−128 dBm)

This value of −128 dBm results when you have a satellite roughly 22,000 miles (35,406 km) away operating at 435 MHz on mode J or JL, with an EIRP output of 2.5 watts (due to uplink station limitations and/or the amount of activity on the satellite). The receiving antenna has a gain of 14 dBi and you're using SSB filters (2.1 kHz) in your receiver. The power (P_{ant}) at your antenna terminals is determined by the strength of the signal, its path loss to the antenna, and your antenna gain:

$P_{ant} = EIRP\ (dBm) - \text{path loss}\ (P_{loss}) + \text{ant gain}$

An EIRP of 2.5 watts equals 34 dBm. The path loss is computed by:

$$P_{loss}\ (dB) = 10\ Log\ [(4\pi \times \text{distance meters})/\text{wavelength meters}]^2$$
$$= 10\ Log[(4\pi \times 35{,}406{,}000)/0.68]^2$$
$$= 176.2\ dB$$

Therefore:

$$P_{ant} = 34 - 176.2 + 14$$
$$= -128.2\ dBm \text{ at the antenna terminals}$$

Antenna and sky noise (−145 dBm)

To compute the noise received from the atmosphere (sky) and generated in the antenna, you must consider the atmospheric and antenna "noise temperature"[1] (the temperature at which the noise from a reference resistor noise standard is comparable to the noise in the atmosphere), and the receiver bandwidth (the noise that the bandwidth of the receiver will let through). Use the following formula:

$Noise_{(A+S)}\ (W) = k \times \text{sky/ant noise temp (Kelvin)} \times \text{bandwidth (Hz)}$

where k = Boltzmann's constant = 1.38×10^{-23} joules/Kelvin

noise temp = 100 Kelvin[1] (typical)

bandwidth = 2100 Hz

Therefore:

$$N_{(A+S)} = (1.38 \times 10^{-23}) \times 100 \times 2100$$
$$= 2.9^{18}\ watts$$
$$= -145.4\ dBm$$

Component noise

The noise generated within each of the components is determined by the following general formula:

$N_{pwr}\ (W) = GktB$

where G = gain of component

k = Boltzmann's constant ($1.38 \times 10^{-23} J/K$)

t = noise temperature of component (Kelvin)

B = bandwidth of system (2100 Hz)

The formula stated in dBm is:

$$N_{pwr}\ dBm = G\ (dB) + 10\ Log\ \frac{ktB}{0.001} \qquad \textbf{(1)}$$

The only item you don't know for each component is its noise temperature. However, you do know the noise figure (NF), so temperature may be derived as follows:

$$T_{comp} = 290\ [antilog\ (NF/10) - 1] \qquad \textbf{(2)}$$

Use formulas (1) and (2) in each of the following derivations.

Coax noise

The coax provides a 2-dB loss in the system; therefore, its noise figure (as a passive component) is also equal to that amount.

$$T_{coax} = 290\ [antilog\ (2/10) - 1]$$
$$= 169.6\ Kelvin$$

$$N_{pwr} = -2 + 10\ Log\ \frac{k \times 169.6 \times 2100}{0.001} \qquad \textbf{(3)}$$
$$= -145.1\ dBm$$

Preamp noise

The preamp noise figure is 0.5 and its gain is 20 dB.

$$T_{preamp} = 290\ [antilog\ (0.5/10) - 1]$$
$$= 35.4\ Kelvin$$
$$N_{pwr} = 20 + 10\ Log\ \frac{k \times 35.4 \times 2100}{0.001}$$
$$= -130\ dBm$$

Receiver noise

The receiver noise figure is 5.0. Its gain is 10 dB.

$$T_{rx} = 290\ [antilog\ (5/10) - 1]$$
$$= 627.1\ Kelvin$$

$$N_{pwr} = 10 + 10\ Log\ \frac{k \times 627.1 \times 2100}{0.001}$$
$$= -127.4\ dBm$$

How to "add" power expressed in dBm

The adding of different dBm power levels to arrive at noise totals is not necessarily an intuitive task, so I'll discuss it here. Power in dBm is a log function with respect to a standard reference value (1 mW), and values can't be added directly. Instead, they must be converted back to power (in watts, or milliwatts in our example), added, and the total reconverted to dBm. As an example, add the coax noise (C) and the combined antenna plus sky noise (A+S) levels of **Figures 1** and **2**. These values are −145 and −147 dBm, respectively.

The formula for converting power to dBm is:

$dBm = 10\ Log\ (\text{power in mW})$

The inverse of this is the formula for converting dBm to power:

P_{mW} = antilog (value in dBm/10)

Taking the values:

$antilog\ (145/10) = 3.16 \times 10^{-15}\ mW$

$antilog\ (147/10) = 2.00 \times 10^{-15}\ mW$

$\text{Total power} = 5.16 \times 10^{-15}\ mW$

Converting back to dBm:

$$P_{dBm} = 10\ Log\ (P_{mW})$$
$$= 10\ Log\ (5.16 \times 10^{-15})$$
$$= -143\ dBm$$

REFERENCE

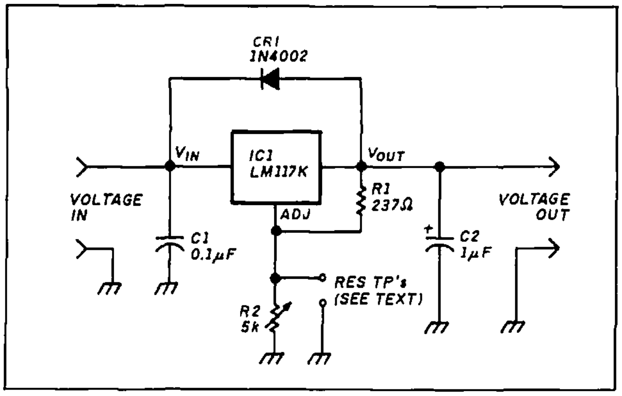
1. *The Satellite Experimenter's Handbook*, ARRL

VARIABLE VOLTAGE REGULATOR

By Howard Weinstein, K3HW, 15 Lakeside Drive, Marlton, New Jersey 08053

The variable voltage regulator (VVR) is a versatile and indispensable device for use on the workbench or in the shack. It lets you adjust the output voltage of a fixed DC power supply between 1.2 and 37 volts DC, and will supply output current in excess of 1.5 A. The circuit incorporates an LM117K three-terminal adjustable output, positive voltage regulator in a TO-3 can. Thermal overload protection and short-circuit current-limiting constant with temperature are included in the package. This device is *almost* blow-out proof!

FIGURE 1



Circuit diagram—VVR.

Circuit description

The LM117K is a three-terminal floating regulator. During operation, the LM117K develops and maintains a nominal 1.25-volt reference (V_{ref}) between its output and adjustment terminals. This reference voltage is converted to a programming current (I_{prog}) by R1 (refer to Figure 1), and this constant current flows through R2 to ground. The regulated output voltage is determined by:

$$V_{out} = V_{ref}(1+R2/R1) + I_{adj}\,R2$$

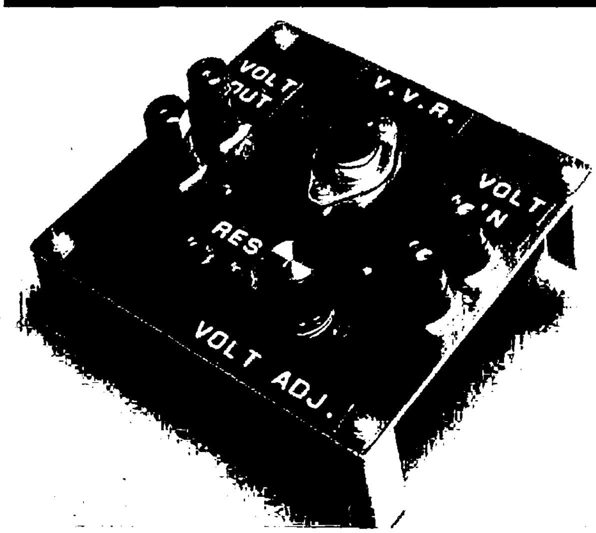
Capacitor C1 reduces sensitivity to input line impedance. Capacitor C2 reduces excessive ringing. Diode CR1 prevents C2 from discharging through the IC during an output short.

Construction notes

Any available enclosure will suffice for building the VVR. For my project, I installed the parts on a piece of aluminum scrap and attached ceramic standoffs (refer to Photo A and Figure 2). The circuit can be used in your own power supply, or even in a piece of equipment that requires tight regulation. Be creative!

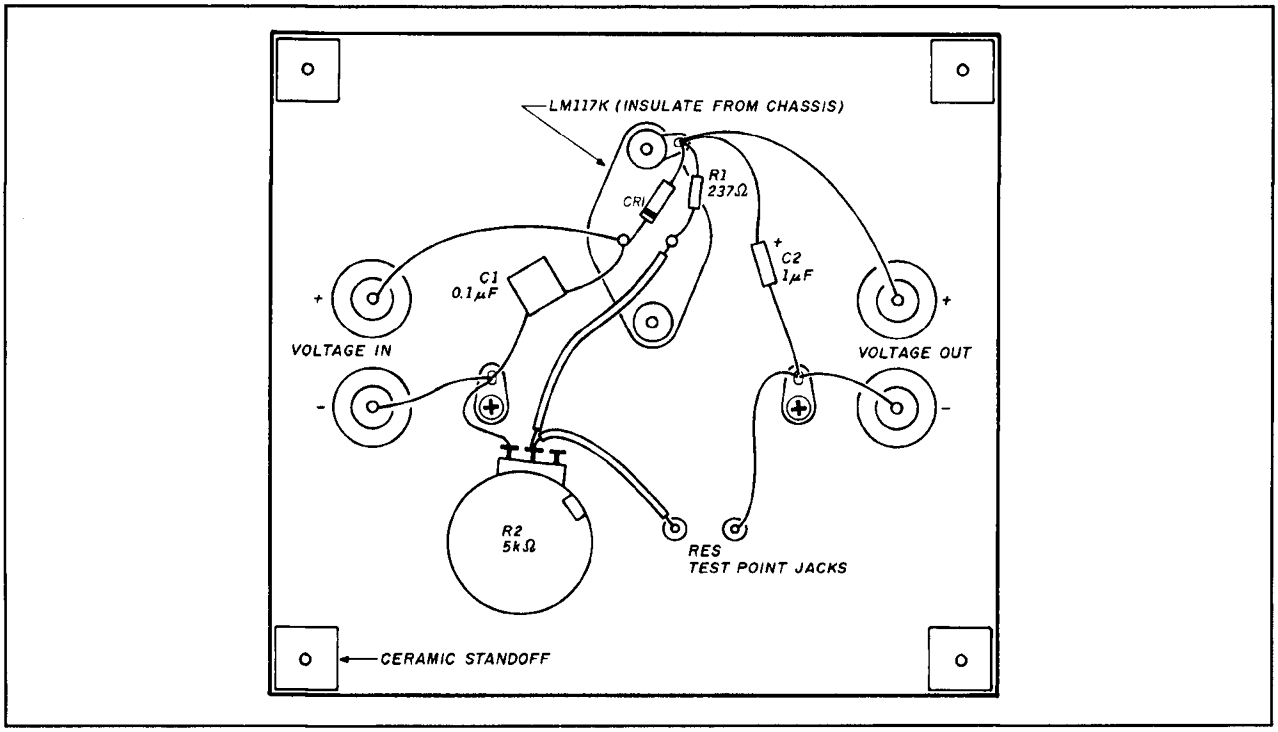
When installing programming resistor R1, locate it as close to the regulator as possible to minimize line drops

PHOTO A



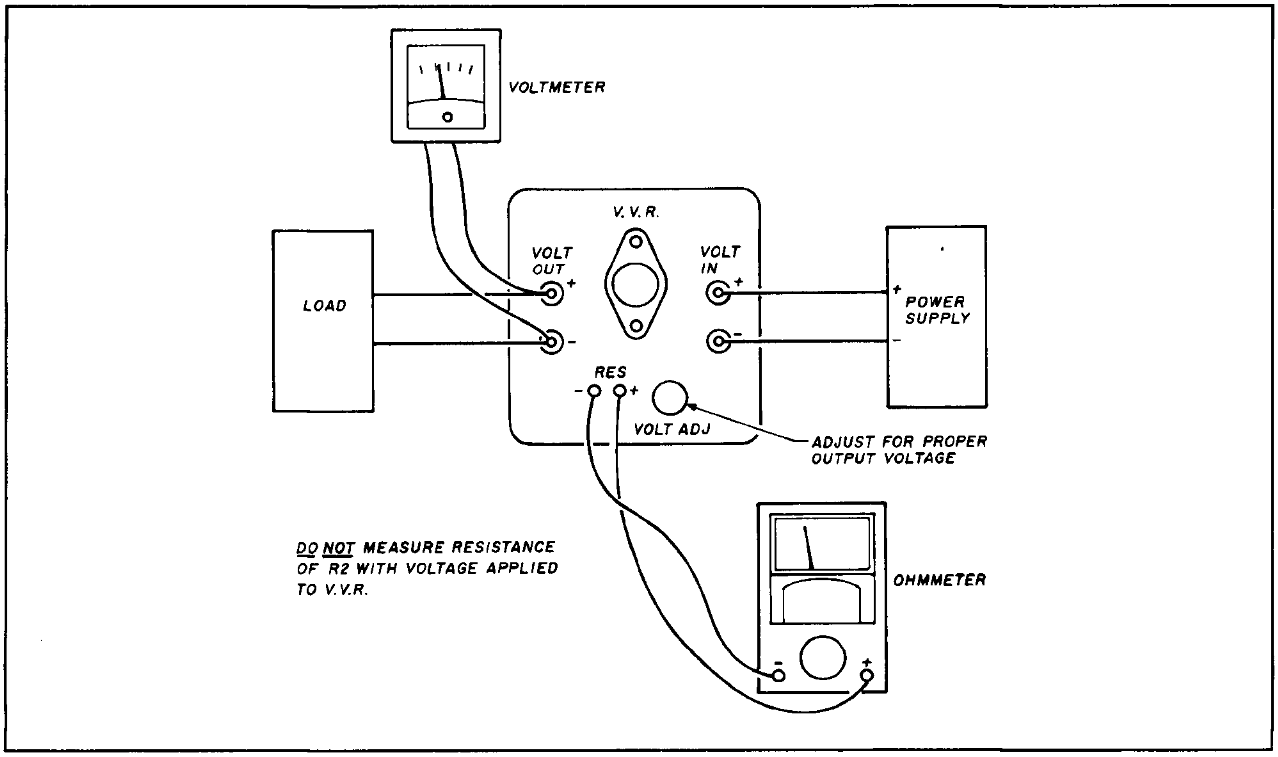
Top view of VVR showing ceramic standoffs.

FIGURE 2



Bottom view—VVR.

FIGURE 3



Typical test setup.

PARTS LIST

CR1	*1N4002 or equivalent*
R1	*237 ohm, 0.25 watt*
R2	*5000-ohm potentiometer, linear taper*
C1	*0.1-μF disc*
C2	*1.0-μF tantalum electrolytic, 100 volts*
IC1	*LM117K*

MISCELLANEOUS
Enclosure, mounting plate, standoffs
Five-way binding posts (4)
Female test jacks (2)
TO-3 insulator kit

which may appear in series with the reference. The ground end of R2 can be returned near the load ground to provide remote ground sensing and improve load regulation. The test point jacks labeled "RES" are provided so you can measure the resistance of R2 when determining the value for a *fixed* resistor. This is necessary when designing regulator circuits for single fixed-voltage regulators.

Caution: Do not measure resistance at the "RES" test point jacks with voltage applied to the VVR! You will damage your ohmmeter!

Remember that V_{out} on the LM117K is the transistor case. Therefore, it must be carefully mounted and properly insulated from chassis ground.

Applications

As I mentioned earlier, the uses and applications for this simple, easy-to-build project are limitless. I have used it at my place of employment for designing fixed-voltage regulators. I use it on my workbench at home with an old military surplus 24-volts DC power supply to provide 12 and 5 volts DC for various projects. I have included the circuit in all of my portable QRP gear, and have built an outboard regulator which I use in the mobile to protect an IC-37A from surge damage. Refer to Figure 3 for a typical test-bench setup.

Parts availability

All of the components used in the VVR are readily available through Radio Shack retail outlets and most mail-order houses. I have assembled a VVR parts kit consisting of IC1, TO-3 insulator and mounting kit, C1, C2, CR1, R1, and R2 with instructions, diagrams, and schematic for $13.00 plus $2.00 shipping. Send a check or money order for immediate delivery.

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COMMON-POINT GROUNDING: LIGHTNING PROTECTION FOR REPEATERS

Practical tips to minimize damage at your repeater site

Peter J. Bertini, K1ZJH, 20 Patsun Road, Somers, Connecticut 06071

Many of us don't worry about lightning until after it's done some damage. It's almost impossible to protect your equipment fully against a direct hit, but you can still take steps to avoid most lightning damage.

What is lightning?

Lightning can be compared to RF energy. This analogy may not be entirely accurate, but both share similar characteristics. Series impedance will hinder lightning's path, just as it does RF. A recent article on lightning and commercial radio sites mentioned that a typical lightning strike could produce a 1000-volt differential between the top and bottom of a 6-foot communications rack! Resistance has little to do with it; it's the result of the 1-μH inductance of an average rack frame. Every μH of inductance offers enough impedance (to lightning) to cause a 1000-volt drop. A lightning bolt can carry currents in excess of 60,000 A and hundreds of millions of volts.

Transverse and common mode

Transverse and common-mode voltages are two forms of foreign voltages that affect single-pair lines. The pair of wires in question could be the AC power line, the autopatch phone line, or antenna feedline.

Transverse-mode voltage appears across the line. Spikes, transients, or other glitches imposed on AC line voltage fall into this category. Many hams use coaxial arresters on HF dipole antennas for transverse protection.

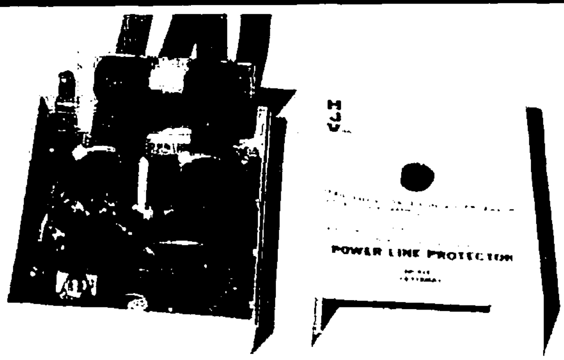
A common-mode voltage is one that is in phase (zero potential) across the wire pair; it's measured from one or both wires to a third point. For example, imagine that lightning strikes the power lines outside your house on both sides of the line, simultaneously. Theoretically it's possible that the line voltage would remain unaffected, while everything that's plugged into it is suddenly millions of volts above earth ground!

Of course this doesn't happen in real life. Both transverse and common-mode voltages will appear on antenna feedlines, power, or phone lines when hit by lightning. Our friendly HF'er, with his dipole and coaxial arrester, probably has a good earth ground tied into his station. He's using forms of both common and transverse-mode protection, though he may not know it. (Sometimes common mode is referred to as longitudinal mode; transverse mode may also be called differential mode.)

Protective devices

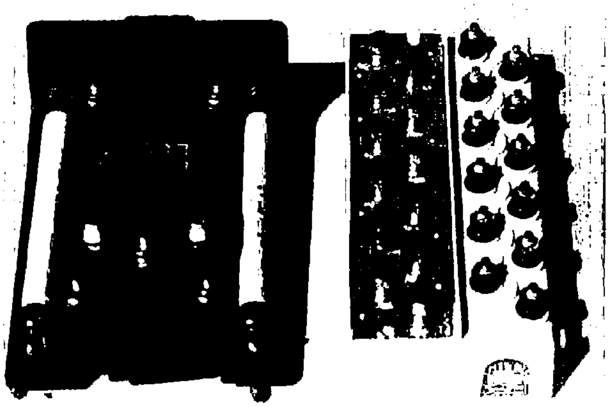
Photo A shows AC surge suppressors often used by commercial and Amateur installations for AC power line protection. These are professional units, not to be confused with the low-cost variety sold in many stores. They contain gas discharge devices, MOVs, and fuses for transverse and common-mode protection. Telephone installers use something like the Cook Electric suppressor shown in **Photo B**.

PHOTO A



Typical AC line protection device.

PHOTO B



Cook Electric model 600 phone line protection device uses high-voltage fuses and gas discharge cartridges for phone line protection. Also shown is multiple phone line protection block with replaceable gas discharge cartridges.

These units use high-voltage fuses and gas discharge devices to protect the customer's equipment.

A typical repeater station will have a good-quality surge suppressor installed at the AC outlet. There's also a phone company arrester at the service drop for the autopatch line. The repeater cabinet is well grounded, as well as the antenna tower. Everything's been done "by-the-book," but when lightning strikes two weeks later, the repeater suffers major damage! What went wrong?

Lightning looks for the shortest path

Here's what might happen when lightning strikes. Suppose telephone installers run 60 feet of ground wire between protection blocks and the nearest ground. Where's a lightning strike going to go after hitting the phone line? When it reaches the protection block, the lightning seeks the shortest path to ground. The phone company's ground gives some protection, but the rest heads for the well-grounded repeater! Maybe 5 percent of the charge makes it to the repeater, perhaps only a few thousand volts. It travels through the autopatch (poof!) and finally to ground.

Let's say there's a commercial base in the same building. His radio takes the hit, not yours. He has grounds and AC protection just like yours. He's also at the end of the AC leg feeding your repeater. Most of the strike is shunted to his base station grounds. What wasn't dissipated heads back towards the service entrance ground. The current races by your outlet, the suppressor fires, and the lightning finds the shortest path — through your repeater power supply into that good earth ground you thoughtfully provided. When the gas arresters fired, all three AC leads — white, black, and ground — became one common ground path.

What about a lightning strike on the repeater antenna? There's a good ground at the tower base, and much of the current is dissipated there. The antenna hard line is bonded to the tower about two-thirds of the way down before leaving for the building. Several feet of ground wire connect the tower base to the ground rods. The tower has inductance, it acts like a voltage divider when the lightning strikes — and the coax is at the tap-off point! The coax offers some resistance to the lightning. Inside the building the equipment ground will dissipate most, but not all, of what's left. The rest finds a path back through the phone and power lines — after passing through your repeater.

Never provide the ground path

As these hypothetical cases illustrate, it's often easy to unwittingly give lightning a path through equipment you had intended to protect. Even the best ground offers limited protection; zero-inductance wire just hasn't been invented yet! Transverse protection is easy, but common-mode protectors need a low-impedance ground to work best. With a high-impedance ground, a transverse voltage can impinge upon the AC power lines' hot, neutral, and ground wires, becoming a common-mode hazard. That's why wall socket-mounted AC suppressors are often ineffective. The ground lead is too far removed from a real earth ground to deal with fast rise time transients.

We've done a lot of lightning protection work at our Soapstone Mountain repeater site in northern Connecticut. Two of our club repeaters share this site, where we have at least one lightning-induced outage every summer.

First, we ran the antenna hard-line cables down to the tower base and bonded them to the tower's grounding system. We sealed everything with 3M's Scotch-Kote™ to protect the aluminum coax from galvanic action. All our antennas' elements are at DC ground potential. Running the coax down the inside of the tower, instead of on an outside leg, might offer some additional protection. Because lightning acts like RF, the skin effect would minimize currents on cables inside the tower.

It's okay to have one ground rod at the tower base. But it's even better to drive additional ground rods several feet out from each tower leg, increasing the size of the ground field. Use heavy copper straps to bond the ground rods and lower legs together. Ground wires must be short; avoid sharp bends. Some Amateurs believe that grounds aren't needed if a tower is set in concrete. Don't fall for this old wives' tale!

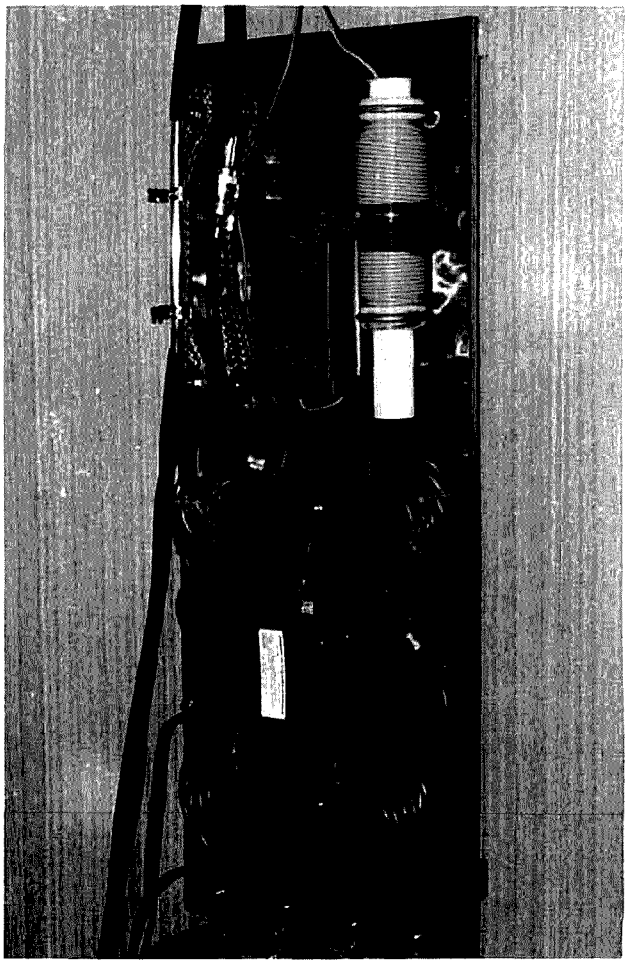
Chemical ground rods work best. They are expensive — about $150 apiece. These rods are hollow pipes filled with a special chemical. Small holes along the pipe allow a small amount of chemical to leach into the soil, improving the ground conductivity.

Use the longest ground rods possible. Stay away from the kind sold at TV shops; they are too short to be of much use. Electrical supply dealers carry the larger sizes. Some mountaintop locations are rocky enough to prevent you from driving a ground rod. If you must, bury the rods horizontally in trenches laid out in "wheel spoke" fashion around the tower. *Never* add rock salt around the ground rods. The short-term benefits will soon be outweighed by the salt's corrosive action.

Multiple ground paths eliminated

Establishing the common-point ground: Our first step in establishing a common-point ground system was to remove all the earth grounding from the repeater racks. We mounted a 2 × 3-foot piece of plywood covered with copper roofing flashing on the wall near the ground wire entrance, and attached the ground wire to this surface (see Photo C). The better the earth ground, the better the common-point ground will work. Lightning arresters for the coax, phone line,

PHOTO C



Common-point grounding system installed at the Soapstone, Connecticut repeater site.

and AC power feed are all mounted on the copper flashing; their ground connections are fastened directly to this surface. This common grounding surface eliminates ground loops through the repeater equipment, and lets the suppressors deal with common-mode transients properly.

AC power line decoupling: The common-point ground is only the first step in isolating the repeater from lightning discharge ground loops. A heavy-duty 100-foot extension cord connects the repeater equipment to the AC line arrester at the common-point ground. The extension cord is wound into a large coil, forming a trifilar choke. The choke's bulk impedance yields a poor return path for lightning through the repeater. A short extension cord is used betwen the AC arrester and the wall socket. A surge supressor is used at the wall socket with another at the repeater rack for cascaded protection.

Phone line decoupling: Treat the phone line the same way as you would the AC power. We scramble wound a large choke on a 2-inch PVC pipe form using 100 feet of in-house telephone wire, and connected it between the arrester

(mounted on the common ground point) and the repeater. We used the Cook electric model 600 arrester here.

Coax cable decoupling: Fifty feet of low-loss Belden 9913 coax wound into a coil serve as the antenna choke. Use this between the repeater and the coaxial arrester on the common-point ground.

We placed the arresters mounted on the repeater rack close together to limit induced currents through the rack frame. This is a duplication of the common-point ground, except that no earth ground is attached at the repeater cabinet. If the rack is sitting on a concrete floor, tiled or not, it should be raised on wooden two-by-fours to lower capacitive ground coupling.

Loose ends

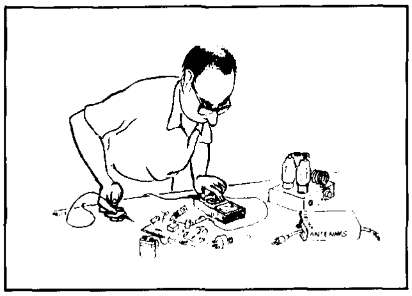
Try to keep everything in one rack; two racks invite multiple ground paths. All racks must be firmly bonded together. Rack interconnections can be protected with chokes or transorbs. The relays can be driven by open-collector outputs before the signal lines leave the rack. Audio transformers in series with audio signal leads going between cabinets will give common-mode isolation and stop ground loops between racks.

Our lightning problems were caused by ground loops between the racks housing our two repeaters. The two controllers were tied together to allow cross control between the two systems. A good lightning hit usually knocked out a few driver chips and both processors. While it might take only about an hour to effect repairs, the processor chips with their piggybacked programmed EPROMs would cost us $150 each!

Finding good protective equipment may be a problem. PolyPhaser Corporation* carries a wide line of lightning protection devices similar to the ones shown and mentioned here. They also offer a 10-percent Amateur discount, and give Amateurs dealer rates on orders over $240.

*PolyPhaser Corporation, 1425 Industrial Way, P.O. Box 1237, Gardnerville, Nevada 89410 1237

Ham Radio Techniques



Bill Orr, W6SAI

Have you met SID?

Nice to have 10 meters active again! The "Bad Old Days" of 1984 to '87, when DX deserted 28 MHz, have faded into the recesses of my mind. Now the band is jumping, except for a few hours now and then when it seems as if somebody has cut the coax to my antenna. I wonder where the signals have gone. Are they gone for good? No! In a few hours the band comes slowly back to life. I have met SID before! I remember him from 20 meters, and here he is once again!

SID (sudden ionospheric disturbance) is a period of time when HF communications are blacked out during daylight hours by abnormally high signal absorption in the D-layer region of the ionosphere. This condition of high absorption may last anywhere from a few minutes to several hours.

The absorption is caused by a solar flare. The flares seem to follow the same 11-year cycle as the sunspots. This means there are more flares and SIDs during a period of high sunspot activity than during a period of low activity. There were only five SIDs during 1944, a year of minimum solar activity. During 1947, a year of maximum solar activity, there were 121 SIDs. It looks as if this figure will be exceeded in 1989.

Figure 1 shows examples of a SID. This recording was taken by Steve Barnes, KH6SB, of the National Oceanographic and Atmospheric Administration (NOAA) at their Ionospheric Station in Maui, Hawaii. It's a record of the strength of the 5-MHz signal of WWV in Colorado on November 13, 1988, as read on the Y-axis. The X-axis represents time and reads from right to left, starting at 2030 UTC. The energy from a solar flare which took about 8.3 minutes to reach the earth occurred at about 2100 UTC. The ultraviolet energy in the flare bombarded the D-layer of the ionosphere, heating it and increasing radio wave absorption. The immediate result was a shortwave fadeout.

The 2300 UTC SID

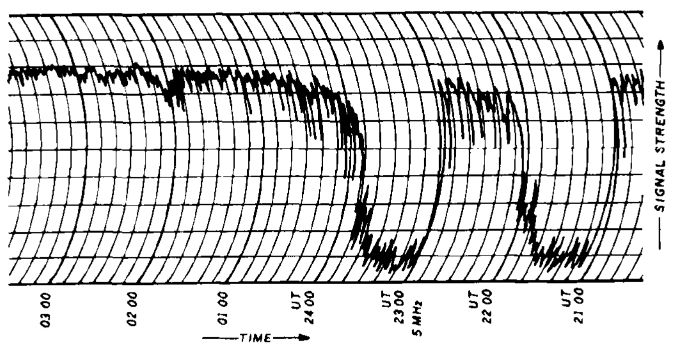
The 2100 UTC fadeout lasted for about an hour and was followed by a second SID, which caused another fadeout starting at 2300 UTC. This fadeout was slightly shorter in duration than the first one. In each case, the onset of the fadeout was quite rapid and the recovery was somewhat slower. Each time, the received signal dropped into the noise level.

Simultaneous recordings of WWV on 5, 10, 15, and 20 MHz reveal that the fadeout is less severe and shorter in duration as the frequency rises. Thus, the fadeout is more pronounced on the 80 and 40-meter bands, somewhat less severe on 20 meters, and minimal on 15 meters. In many cases, 15 and 10 meters are only slightly affected. A more severe SID can cause 15 and 10 meters to drop out, in addition to the lower bands.

A SID early-warning receiver

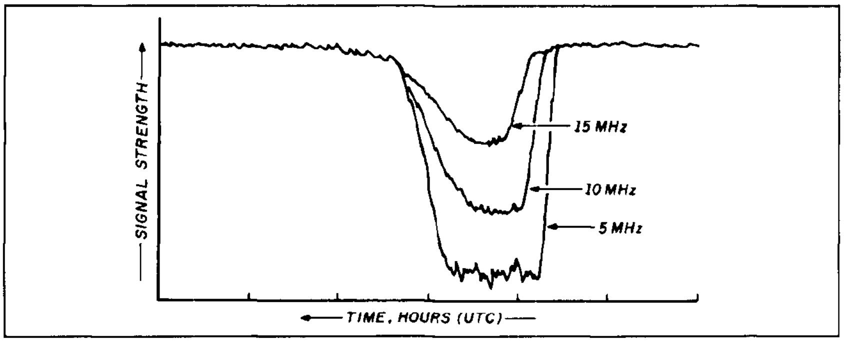
Steve has a quick and easy SID-alert scheme. He suggests you monitor WWV on several frequencies. Radio Shack weather receiver model 12-148 covers 5, 10, and 15 MHz at the touch of a key. Steve added a short antenna to the receiver and set it on 5 MHz. He lets it run at low volume in his ham shack. If 5 MHz drops out, he hits the

FIGURE 1



Recording of signal strength of WWV (5 MHz) taken at Maui, Hawaii, November 13, 1988. About 2100 UTC signal strength drops abruptly, signifying start of SID. Ionospheric effect remains for about an hour, then the signal builds back to normal level. Shortly before 2300 UTC a second SID occurs which lasts approximately 50 minutes.

FIGURE 2



SID blanks out the lower frequencies first, and for a longer period of time. Monitoring the 5-MHz signal of WWV provides an early warning of SID. The particular event shown may have little effect at 30 MHz.

10-MHz key. Poor reception on that frequency indicates a SID may be in progress, so he shifts to 15 MHz. When the latter frequency drops out, Steve notes that 20 and 15 meters are gone — and possibly 10 meters. The SID blacks out the lower frequencies first, and for a longer period of time as compared with the higher frequencies (see **Figure 2**). His little WWV receiver gives him an early warning that the DX bands are about to drop out.

Overcoming the SID

Shift operation to a higher frequency band to overcome SID effects. If you experience a quick fadeout on 20 meters, try 15 or 10 meters. You might get through even though 20 meters seems dead. If that doesn't work, go even higher in frequency.

The SID at VHF

In the 50-MHz region, radio signals can be propagated over long distances by ionospheric scatter occurring mainly in the D-layer. During a SID, D-layer ionization increases and 6-meter scatter signals are enhanced — sometimes by as much as 9 dB. Six meter DX may be jumping while the lower bands are useless. So each SID seems to have a silver lining (at least for the 50-MHz operators).

Polar cap absorption

Polar cap absorption (PCA) takes place in the higher latitudes and may last up to five or six hours. It's usually preceded by a major solar flare which seems to ionize solar protons in the D-layer. The PCA appears one or two hours after the flare and lasts anywhere from a day to nearly two weeks. Since the PCA is associated with a solar flare, it's tied in closely with the sunspot cycle — the higher the sunspot number, the greater the number of PCA events.

The PCA can lower the MUF and boost the lowest usable frequency (LUF) simultaneously, narrowing the usable frequency spectrum. A breakup in the ionospheric layers often accompanies the PCA event, creating "auroral flutter." This flutter is very noticeable on SSB contacts.

DX contacts over the pole (United States to Europe) are difficult to make during a PCA. For example, the path between California and Europe may be closed, but the path from California to North Africa may be open as the Great Circle route of the latter path skirts the edge of the auroral zone.

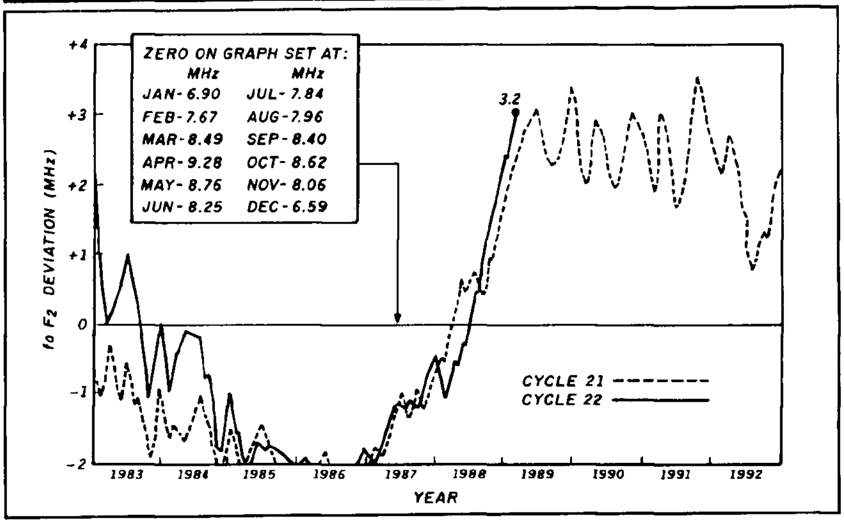
Beating the odds

As the sunspot cycle rises, SID and PCA events increase. However, it's possible for the serious DXer to "beat the odds" during these happenings. The SID blackout is relatively short in duration and may be avoided if you increase the operating frequency. The PCA creates ionization in the D-layer and absorption is less on the lower frequencies. Going from 21 to 7 MHz may do the job. If all else fails, and the bands are dead, sit down and read a good book!

Goin' up, lookin' good

How goes sunspot cycle 22 (the present one) as compared with cycle 21? One way to judge cycle progress is to observe ionospheric reflection. Ionospheric stations do this by transmitting a pulsed signal vertically to the ionosphere. The frequency of the signal is swept between 3 and 20 MHz and the reflected return pulse is monitored. The maximum reflected frequency for a vertical incident wave is about one-third the maximum usable frequency (MUF), at Maui. Thus, if the highest reflected frequency of the

FIGURE 3



Comparison of F_0F_2 for sunspot cycles 21 and 22. The two cycles are superimposed on one graph. The X-axis shows years in cycle 22. The Y-axis represents deviation from average monthly value of F_0F_2. Zero value on graph is determined from *Table*.

pulse is 10 MHz, the MUF is about 30 MHz. You can observe the reflected signal on an oscilloscope and record it on a tape.

The average monthly value of the signal reflected from the F-layer has been observed for many years. The easiest way to get a quick fix on F2 reflection is to plot the deviation in MHz from the average monthly value for each month. This has been done for you in **Figure 3**. The zero point on the X-axis changes each month, according to the chart on the graph. For example, the chart shows that in January 1983 the average monthly value of the F2 maximum frequency of reflection (F_0F_2) was 6.97. The measured value of F_0F_2 during January 1983 deviated from that figure by +2.4 MHz, as read on the Y-axis of the graph. The actual value of F_0F_2 for cycle 22 was 6.97 + 2.4, or 9.37 MHz. The MUF was about three times this figure, or 28.11 MHz.

For cycle 21, the deviation from the average monthly value during January was −0.4 MHz. The value of F_0F_2 was 6.97 − 0.4, or 6.57 MHz. The MUF was three times this value, or 19.71 MHz.

Where we stand now

The most recent ionospheric observation plotted was for February 1989. The zero point on the graph for February (from the table in **Figure 3**) is 7.67 MHz. The deviation is +3.12 MHz, giving an incident reading of 10.87 MHz. The MUF accordingly is 32.61 MHz for that month.

Remember that Hawaii is closer to the equator than the mainland and the MUFs are much higher in that part of the world.

Cycle 22 plots a tantalizing course. As of February 1989 it seems to be running ahead of old cycle 21. You can see that cycle 21 "topped out" at deviations of +3 to +3.7. It never reached a deviation of +4. If by chance a deviation of +4 is noted for April 1990 (where the average monthly value of F_0F_2 is 9.28), the incident measurement would be 13.28 MHz, giving a MUF value of 39.8 MHz.

A quick look at the graph shows that chances of the MUF reaching 50 MHz are slim. But F2 skip has been recorded on 50 MHz in the past! The next six months will give a good indication as to where the MUF is heading. Do you want to place your bets now? I'd place my money on the spring or fall of 1989, 1990, and 1991!

The record cycle of 1958

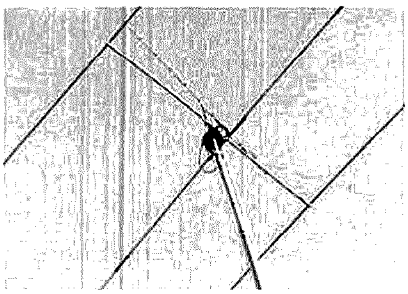
Cycle 19 is the highest sunspot cycle on record; the deviation reached +4.4 during early 1958 with a smoothed sunspot number of 200. During March of that year a new 50-MHz DX record was established when JA6FR in Japan worked LU9MA, LU3EX, and LU2EW in Argentina. About the same time, K6OBO worked LU8AE and LU9EV. Shortly thereafter, 50-MHz DXers in California filled their log books with JA and LU stations, in addition to other South and Central American stations. By the fall DX season, East Coast stations were working Rhodesia in Africa, South America, and European stations in Sweden, Norway, and Ireland. I'm sure these DX records will be broken during this coming cycle!

More on tilt-over towers

My remarks about tilt-over towers in the May column brought some interesting letters. Cal Hoerneman, W4OTS, provided interesting pictures of his freestanding, 50-foot, tilt-over tower (**Photos A, B, and C**). At the top of the tower he has a rotor, a TA-33 triband beam, and an 11-element, 2-meter array. The tower has been up for eight years with no problems.

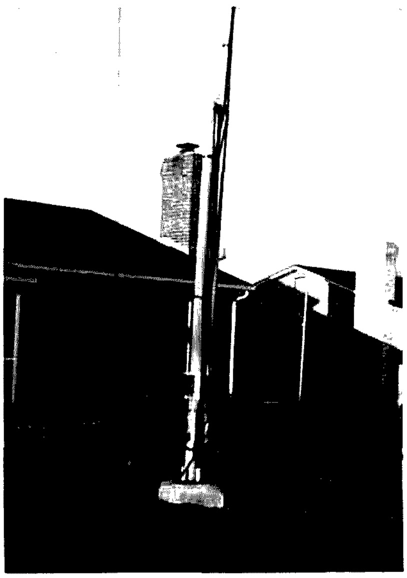
The tower is mounted to a finned ground post set in cement. A local welder constructed the tower out of iron pipe. The bottom section is filled with steel bars to act as a counterweight.* The hoist is the type used to lift a boat onto a trailer.

PHOTO A



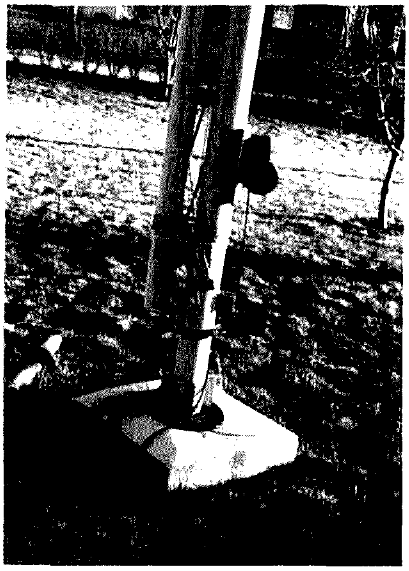
Looking up the 50-foot high tilt-over tower at W4OTS. Tribander, 2-meter beam and rotor are mounted atop a circular metal plate welded to the top of the tower. Tower also supports center-fed inverted-V for 75 meters.

PHOTO B



Base of W4OTS tower. Tower is affixed to ground post sunk in cement. Clevis at top of post permits to tilt over. The mast is locked in position by second clevis near base of the ground post.

PHOTO C



Closeup of ground post and base of mast. Winch is mounted to side of post. Tower was designed following data provided by Bob Haviland, W4MB.

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*It is rebar. It's for mechanical strength in concrete, not counterweight.

Cal notes that the basic information for building a tilt-over tower was discussed by Bob Haviland (ex-W3MR, now W4MB) in the September 1974 issue of *Ham Radio* magazine. Sure enough! When I found the article, I immediately recognized its value and asked if it could be rerun in this issue.* The article was 15 years ahead of its time and any Amateur interested in building a tilt-over tower should read it.

Thanks to Ralph Fowler, N6YC; Phil Dejarlais, WØJHS; and Lloyd Hanson, W9YCB, who also provided information on their towers.

MINIPROP 3.0 propagation program

Sheldon Shallon, W6EL, sent me a "floppy" of his MINIPROP program. It's not based on the older MINIMUF, but on a method developed by the British Broadcasting Corporation (BBC) for predicting MUF. The program extends the predictions to forecast signal levels, take-off angle for the mode, and the percentage probability that the transmission mode exists. It also provides MUF, beam headings for the path, path length, sunrise and sunset times for the path, gray line directions, and more. All of this data is projected for both long and short-path openings.

MINIPROP was used successfully by NOAA to schedule communications with its ozone hole measurement team in the Antarctic.

This program supercedes MINIPROP 2.0. It's designed for use with an IBM PC, XT, AT, PS/2, or true compatible with 320K memory, one floppy (5-1/4 inch) or microfloppy (3-1/2 inch) drive, and PC-DOS or MS-DOS 2.11 (or later version). An 80-column monitor is required. An 8087, 80287, or 80387 math co-processor is strongly recommended, but not required.

Contact W6EL Software, 11058 Queensland Street, Los Angeles, California 90034-3029 for complete information.

*Done! Ed

DESIGN DATA FOR PIPE MASTS

Design your own antenna mast using steel pipe

By R. P. Haviland, W4MB, 1035 Green Acres Circle N., Daytona Beach, Florida 32019

One of the best materials available for building self-supporting antenna masts is steel pipe. It is widely available, uniform in quality, and reasonable in price. A well-designed mast is adequately strong, neat and attractive, and relatively light weight. And, using steel pipe, it's not too difficult to design a fold-over mast which allows all antenna work to be done at ground level. Even maintenance on the mast itself does not require work at any great height.

However, attaining all of these advantages does require some design work. This is particularly important for safety. The purpose of this article is to present a set of design curves which will give a safe and satisfactory design, while using the minimum of material.

Construction

The general construction of a typical fold-over pipe mast is shown in **Figure 1**. At the top are the antenna and rotator, carried by the smallest size pipe. This is inserted into the upper end of the next size pipe for a short distance, and fastened by through-bolts or welding. The second section is inserted into the next larger, and so on. The bottom section is hinged to a fixed upright pipe, which gives the fold-over feature. It, in turn, nests into a larger section of pipe set into the ground. A yoke is provided to fasten the mast to the upright after erection. **Figure 1** shows a block and tackle for pulling the mast to the vertical position, but a winch fastened to the upright may be used instead.

Most mast designs use the widely available standard weight pipe, each size of which nests neatly into the next larger size, over the range from 1-1/2 to 4 inches. Larger sizes still nest, but there is a gap between the walls. Very high masts, or those with unusually heavy top loads, can be built with extra-strong or double extra-strong pipe, but such designs are not considered here as the data are calculated for standard weight pipe.*

Design criteria

Because of the change in diameter, beam formulas cannot be applied to a stepped diameter mast as a whole. Instead, each individual pipe section must be analyzed by itself, as a free body, starting at the top. The section load must then be transferred to the next lower section. This is done by converting the lateral load to a couple, acting across the diameter of the section, then multiplying the couple magnitude by the ratio of pipe diameters to get the top load of the next section. Intermediate antennas can be assumed to be concentrated at the junction of sections. The next section is then considered.

The critical or design load on a section may be caused by wind load when the mast is vertical, or by erection load as the mast is being raised. Both loads should be calculated and the design chosen for the worst of the two.

For wind load, two design winds are commonly used. For most of the country, it is assumed that the worst wind to be encountered is 85 mph, a value to be expected once in 50 years or so. For Florida, the Gulf Coast, and locations

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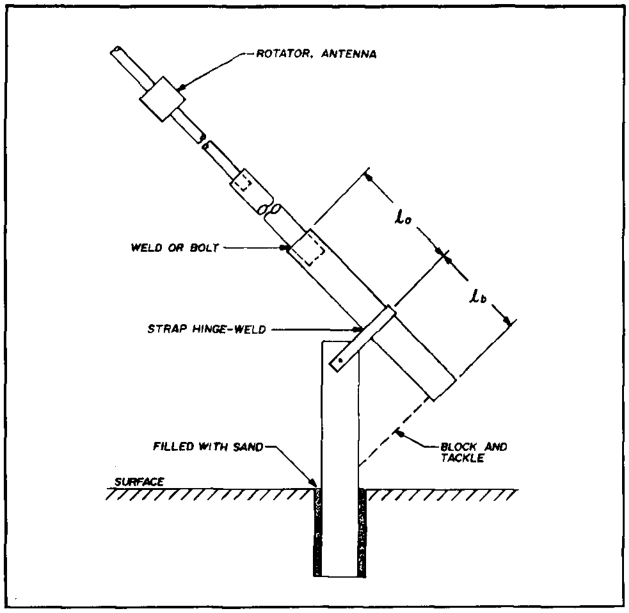
**Standard and extra strong* (ASTM nomenclature) are the two pipe weights commonly encountered. The American Petroleum Institute has a separate designation for well casing, but this is called tubing rather than pipe — although some sizes are identical to pipe sizes. The critical dimensions for standard weight pipe are:

Size	Outer diameter	Wall thickness
4 inch	4.5 inch	0.237 inch
3-1/2 inch	4.0 inch	0.226 inch
3 inch	3.5 inch	0.216 inch
2-1/2 inch	2.875 inch	0.203 inch
2 inch	2.375 inch	0.154 inch

The ASTM recommended fiber stress values for *standard* weight pipe is 20,000 psi (bending). The design procedure presented here uses a 10-percent reduction from this stress figure, based on good used pipe.

Note that the extra-strength and double extra-strength sections do not nest because of thicker walls. Such heavier pipe can be used for the topmost section and for the standing or ginpole section. However, the curves apply only to standard weight pipe or tubing of the sizes given in the table. **Editor**

FIGURE 1



General layout of the fold-over pipe mast (not to scale).

like Cape Hatteras, a maximum wind of 125 mph is also used. Your county engineer can provide the recommended value for your location (see **reference 1**).

During erection there is some deflection, or bending, of the mast. The greatest load occurs when each section is horizontal; this is the loading which must be designed for.

The wind and erection impose two different types of load on the section. One is the concentrated load at the topmost end of a section due to the forces on the section above. The second is the distributed load acting along the length of the section. As the concentrated load becomes larger there is less strength left for the distributed load, so the section length must become smaller. Accordingly, the problem of design is to determine the allowable section length.

The concentrated load during erection is the weight of the antenna, rotator, and sections above the one being considered. The concentrated wind load includes the sum of all wind loads above the section being considered. The usual load is calculated on the basis of projected area. This is the area covered by the shadow of the object. If the object is not symmetrical, like a Yagi beam, the largest projected area is used. The loading depends on whether the object is flat or round, as follows:

Wind loading in pounds per square foot

	85 mph wind	125 mph wind
Flat objects	30.3	65.9
Round objects	18.1	39.0

The projected area is often given in the instructions for commercially made antennas and rotators. It is easily calculated from the dimensions of the element.[1]

Given this concentrated load on the topmost section, design of the mast itself involves solving section load equations for allowable section length. To simplify this process, the equations have been reduced to a series of graphs — Figures 2 and 3 for load during erection, and Figures 4 A and B and 5 A and B for wind loads. Use of these curves will be explained through an example.

Example

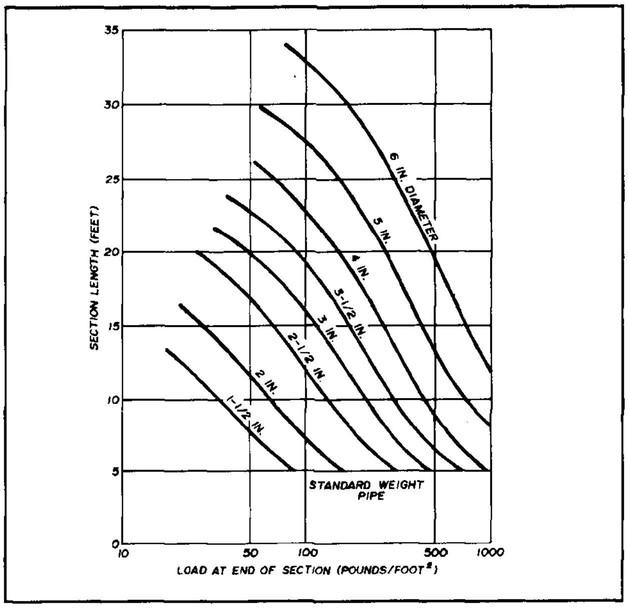
Assume that the design is for an all-tubing 6-meter antenna, having 2 square feet projected area and weighing 15 pounds. A small TV rotator is available, having 1/2 square foot of mostly flat plate area, and weighing 8 pounds. This area is not subjected to unusual winds. Mast height is 40 feet.

The concentrated load on the top section is 15 + 8, or 23 pounds. Entering **Figure 2** at the bottom with this weight and moving upwards, it is seen that the top section could consist of 12 feet of 1-1/2 inch pipe, 16 feet of 2-inch pipe, or 20 feet of 2-1/2 inch pipe. In keeping with the scale of the antenna, suppose the 1-1/2 inch diameter pipe is used.

The concentrated wind loading is due to 2 square feet of antenna and 1/2 square foot of rotator. From the table above, the loading is (2 × 18.1) + (0.5 × 30.3), or 51 pounds per square foot. Reading upward from this load on **Figure 4**, it is seen that the maximum allowable length for 1-1/2 inch pipe is 8 feet. Since this is the critical value, it becomes the length of the topmost section.

Assume that the sections are to be fastened by welding, with 6-inch insertion into the next section. From **Figure 3**, the weight of the 8-1/2 foot total of the top section is 23 pounds. The wind loading on the exposed 8 feet from **Figure 5** is 25 pounds per square foot. Thus, the weight load at the top of the second section is 23 + 23, or 46 pounds and the wind loading is 51 + 25, or 76 pounds per square foot.

FIGURE 2



Allowable section length at erection for standard weight pipe, fiber stress = 18 kips. (The units of force are pounds, tons, kilograms, etc. In engineering practice the word *kip* is frequently used; it merely means 1000 pounds. Thus 18 kips can also be written 18,000 pounds. Ed.)

Using **Figure 2** again, the maximum allowable length of the next section with the nesting 2-inch pipe is 11-1/2 feet for erection loads. From **Figure 4**, the allowable length for wind loads is 9 feet, which becomes the section length. Proceeding as before, the loads on the next section are 46 + 35, or 81 pounds during erection, and 76 + 35, or 111 pounds per square foot for wind.

Again, using **Figures 2** and **4**, the allowable length of 2-1/2 inch pipe is 13 feet for erection load, and 12-1/2 feet for wind load. The 12-1/2 feet is the length ℓ_a in **Figure 1**. The load on the section ℓ_b in **Figure 1** is the same in magnitude, so this part could also be 12-1/2 feet long. However, a stock length for pipe is 21 feet. Assume that this is all that's available. Then the third section will need to end 1 foot above ground to reach the desired 40-foot total height. This is not unreasonable.

If a counterweight is added to the lower part of the third section to just balance the top weight, the erection loads on the fixed upright pipe are essentially zero. Even if no counterweight is used, the balancing effect of the part ℓ_b of **Figure 1** reduces the load on the upright to less than the load on section ℓ_a of **Figure 1**. Thus, if the upright is no smaller than the lowest mast section, it will have adequate strength for erection.

The wind load on the upright is that of the upper sections plus that on the top 10-1/2 feet of the lower section, plus some amount on the upright. Assume that the upright is fully exposed (a safe assumption). The wind load to the top of the upright is 111 + 55, or 166 pounds per square foot maximum, the exact value depending on the final choice of upright length. From **Figure 4**, the upright can be only 6 feet long if it is 2-1/2 inches in diameter, or 13 feet long if it is 3 inches in diameter. Since 12-1/2 feet is needed as a minimum, this is just about right (half of the 21-foot length of the 2-1/2 inch section, plus 1-foot ground clearance).

Even with the curves, the process is somewhat tedious and it's easy to make mistakes. Most of the tedium and mistakes can be avoided by transferring the relations to a computer program.*

While this design is intended to be used without guys, they can be added for greater safety or increasing the allowable wind load. Usually the wall thickness is sufficient to withstand the compressive forces caused by guy tension, but this should be checked if a guyed design is attempted.

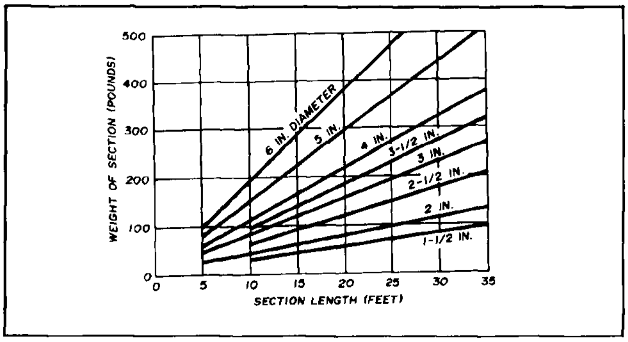
Factors affecting the length of pipe buried in the ground are discussed below. For this example, assume that this is 10 percent of mast height, or 4 feet. Total upright length is thus 13-1/2 + 4, or 17-1/2 feet. The jacket section buried in the ground needs to have 1-inch clearance, so it must be a 4-foot length of 5-inch diameter pipe.

The results of this design example are:

Top section: 1-1/2 inch diameter top section, total length 8-1/2 feet, exposed 8 feet.

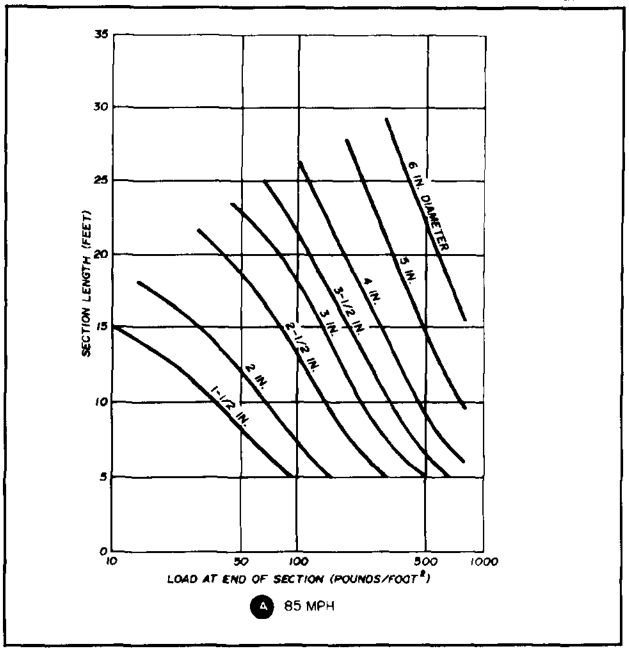
Second section: 2-inch diameter second section, total length 9-1/2 feet, exposed 9 feet.

FIGURE 3



Weight of standard pipe.

FIGURE 4A



Maximum allowable section length for standard weight pipe with winds of 85 mph (fiber stress = 18 kips).

Lower section: 2-1/2 inch diameter lower section, total length 21 feet, hinge at 12-1/2 feet, 1-foot ground clearance at bottom.

Upright: 3-inch diameter upright, total length 17-1/2 feet, exposed 13-1/2 feet, buried 4 feet.

Jacket: 5-inch diameter, total length 4 feet, all buried.

If necessary, this design could be carried higher, using larger pipe sizes.

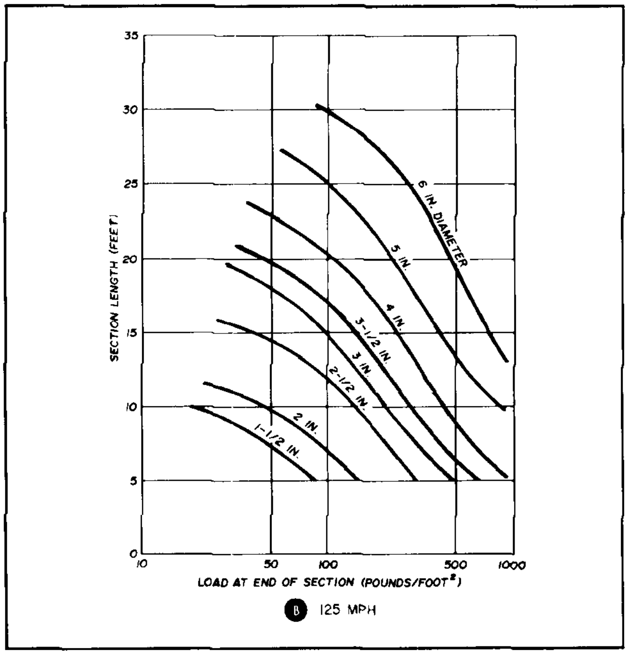
It is often necessary to try several initial assumptions as to length and diameter of the top section. With a little practice, this can be done in a few minutes.

Construction details

The 6-inch overlap assumed in the example is sufficient for either welding or bolt fastening. Bolts are suggested as they are simpler and allow disassembly.

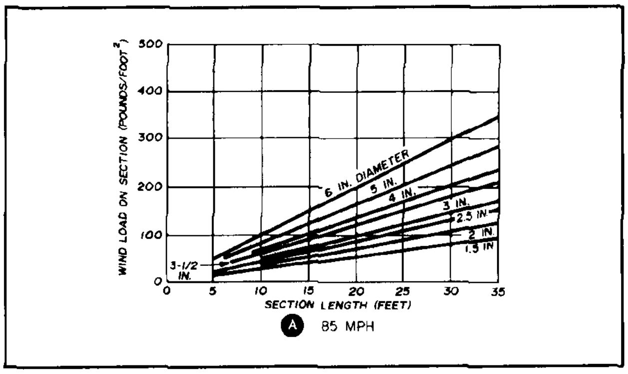
*Such a program is included in the author's "Practical Antenna Design and Analysis" available from MiniLab Books, Daytona Beach, Florida, 32021-1086, or from the HAM RADIO Bookstore. Editor

FIGURE 4B



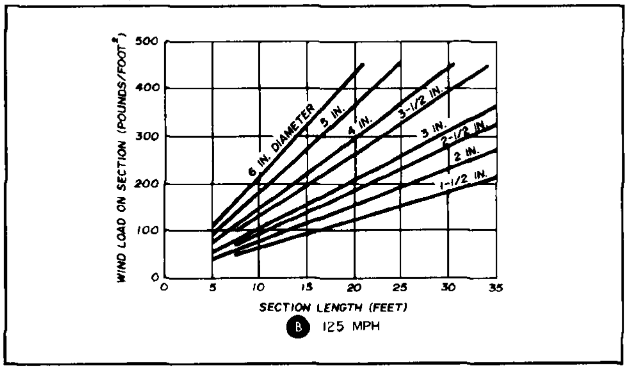
Maximum allowable section length for standard weight pipe with winds of 125 mph (fiber stress = 18 kips).

FIGURE 5A



Wind loading for standard weight pipe, 85 mph winds.

FIGURE 5B



Wind loading for standard weight pipe, 125 mph winds.

Two bolts at right angles passing completely through both pipe sections are recommended. The thread root diameter should be no less than the thickness of the larger section. As a refinement, drill and tap the outer pipe for alignment screws to be placed just above the top bolts and just below the bottom ones. These are a necessity if the pipe sections differ much in size (for example, if a 4-inch pipe is to be nested into a 5-inch one). The space between pipes can be filled with silicon rubber in the final assembly.

The "U" strap hinge shown in **Figure 1** should have a thickness at least as great as the wall thickness of the pipe it supports. For strength in bending, its width can be about 12 times the thickness. The pin hinge diameter should be at least twice the wall thickness for bending strength. (These bending forces are likely to occur in handling and erection, and are difficult to estimate).

A second "U" and pin can be placed at the very bottom of the movable masl part to anchor it to the ginpole section. The pin can be drilled for insertion of a padlock, to prevent sabotage or tampering. A bicycle chain does nearly as well. Another refinement is to wrap both the ginpole and lower pipe section with several turns of barbed wire, about 8 feet above ground level. This helps prevent anyone from climbing the mast.

The suggested assembly routine is to mark each section with the bolt locations and the nesting length. Then lay the pipe on the ground, with blocks or pegs to hold it in place. Use a cord to get the correct alignment. Drill one of the bolt holes, insert the bolt, and then drill for the other one. Without shop facilities, it's nearly impossible to pre-drill these holes and have them line up.

Weight and area aloft can be reduced by turning the entire mast. This complicates the attachment to the ginpole section. However, the bearings needed can be simple sleeve bearings — essentially "U" straps with filler blocks, plus bearing rings attached to the pipe. The vertical load on these bearings can be removed by mounting a heavy-duty rotator under the very bottom of the mast and using a scissors jack to raise the rotator and mast just enough to take the load off the straps. Look at one of the commercial designs for ideas.

Since guys are not needed, the rotating mast type is excellent for stacked beams.

Foundations

Because of the great variability of soils, it isn't possible to provide a set of all-purpose design curves for foundations. The best way of proceeding is to work with your county engineer, and use the practices developed for your particular area. The local power or telephone company should also be able to supply the necessary data.

For reasonably good soils, like firm loams or clays, a good starting point is to assume that the foundation depth is equal to 10 percent of the height, with the jacket set in concrete of sufficient size to keep the soil load to a safe value. A maximum load of 4000 pounds per square foot is often used, with the design adjusted to give a 100-percent safety factor above the design load. If you haven't done this work

before, the county engineer can show you the steps.

The ginpole pipe section going into the ground must be protected from rust and corrosion on the inside and outside. This is especially important to prevent rusting at the waterline, if free water is present.

Usually, adequate protection can be assured by painting the pipe with a grout of cement and water. Even better protection can be obtained by wrapping the outside with several layers of builder's felt, painted with cold application roofing tar as the felt is wound on.

Pipe sections can be sealed with wooden plugs and a layer of silicon putty. The entire mast and all hardware should be painted as a last step before installation of the antennas. Aluminum Rustoleum™ is suggested, as it is compounded to remain flexible, and is nearly as good for rust prevention as a zinc coating.

Safety

More and more communities are requiring permits for structures of this type. There may be height restrictions. Know your local laws!

In many areas, one requirement for obtaining a permit is certification by a professional engineer. You can usually save time and cost by doing the preliminary design and analysis yourself; use standard formulas or the curves here. Do the work neatly, in an easy-to-follow form. The engineer will want to at least check the method and critical loads. If he wants to do a complete analysis, you'll be able to use it to argue about the cost of insurance coverage (a generous policy is recommended).

Any antenna mast can become a hazard if good safety practices are not followed. Remember that a quarter- or half-ton of steel 30 to 70 feet in the air is no toy. If you lack experience or don't have the proper facilities, get qualified help. Always remember, *safety is no accident.* hr

REFERENCE

1. John J. Nagel, K4KJ, "How to Calculate Wind Loading on Towers and Antenna Structures," *Ham Radio*, August 1974, page 16.

This article first appeared in the September 1974 issue of *Ham Radio*. Editor

ICOM's new AH-3 HF antenna tuner

ICOM introduces the fully automatic AH-3/HF antenna tuner. The new AH-3 matches any frequency in the Amateur band. It features:

- Full automatic tuning
- Memory channels
- Durable, weather resistant housing.
- Low-power tune-up
- Simple installation

The AH-3 can also be used for HF mobile operation. It installs in your trunk and tunes automatically. The optional AH-2b antenna element is available and includes a bumper mount system for holding an 8.2-foot stainless steel antenna element. The AH-3 and AH-2b system allows you 3.5 to 28-MHz mobile operation.

The AH-3 is priced at $489. For additional information contact ICOM America, Inc. 2380 116th Avenue N.E., PO Box C-90029, Bellevue, Washington 98009-9029.

Circle #302 on Reader Service Card.

New features available for the multi-mode data controller

MFJ Enterprises, Inc. originally released the MFJ-1278 (priced at $249.95) with transmit and receive in seven modes: Packet, RTTY, WeFAX, SSTV, CW, ASCII, and Contest Memory Keyer. MFJ announces two new modes: Navtex receiving and AMTOR transmit and receive.

There are also two new features for the MFJ-1278 Packet mode: the new Easy Mail™ Personal Mailbox and a new KISS Interface for TCP/IP compatibility.

New terminal software for the Macintosh computer, the MFJ-1287 Starter Pack with interface cable and Wefax printing to screen, is available for $19.95.

Existing programs for the IBM (MFJ-1284) and Commodore (MFJ-1282 disk/MFJ-1283 tape) are available with cable and instructions for $19.95 each.

For more information contact any MFJ dealer or MFJ Enterprises, Inc., PO Box 494, Mississippi State, Mississippi 39762, or call toll free 800-647-1800.

Circle #303 on *Reader Service Card.*

RADIO WORKS' Discovery Catalog

The RADIO WORKS' 1989 discount catalog is a source book of wire antenna systems, components, and accessories.

It includes 56 pages of mobile and base antennas, mounts, antenna wire, insulators, coaxial connectors and cable, surge protectors, coax switches, Dacron* and MilSpec support line.

Pre-built antennas include RADIO WORKS' two new versions of the Carolina Windom*, and a high performance, 3/2 wavelength loop called the BigSig Loop*. Also featured are the new InTreeVert* and the 16-foot MicroDipole*. All RADIO WORKS' antennas are available for the new WARC bands.

The SWL section features new antennas. There are also SWL products and active antennas to preselectors from other manufacturers.

You can select from ten different balun models including the B4-2KX Current-type* and RemoteBalun*.

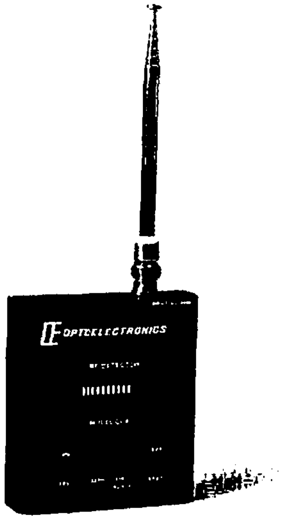
The RADIO WORKS' 1989 catalog costs $2 but is FREE to all *Ham Radio* magazine readers. Include $1 for first-class postage if you want speedy delivery. Contact the RADIO WORKS, Box 6159, Portsmouth, Virginia 23703. Phone (804)484-0140.

Circle #304 on Reader Service Card.

New CCB handheld RF detector

Optoelectronics, Inc. introduces the new CCB handheld RF detector. Applications include checking the output from small or large transmitters used in radio telemetry, two-way radio, ham radio, garage door openers, RC transmitters, cordless phones, cellular phones, marine radio, aircraft radio, CB, police, fire, or other radio services.

The CCB has a ten-segment LED bar graph readout, two-stage wideband RF amplifier, and a forward biased hot carrier diode for a detector. The detector output is filtered and fed to the log output bar graph driver circuit. Each segment responds to a 3-dB step increase in signal strength. Screwdriver adjustable pots are provided for zero and full-scale adjustment.



The CCB is available for $99.95 from Optoelectronics, Inc. 5821 N.E. 14th Avenue, Fort Lauderdale, Florida 33334 (800) 327-5912. (In Florida call (305) 771-2051.) Accessories include the model TA-100S telescoping BNC antenna for $12 and the CC-12 vinyl zippered carry case for $10.

Circle #305 on Reader Service Card.

New "soft-side" tool kits

Hand Tool Industries has announced the its new soft-side zippered tool kits.

These tool kits are designed for service engineers and technicians who work on data processing equipment and comparable types of electro-mechanical devices.

The kits are available in brown heavy-duty padded vinyl; many are Cordura* material. Each kit has individual tool pockets and heavy-duty zipper.

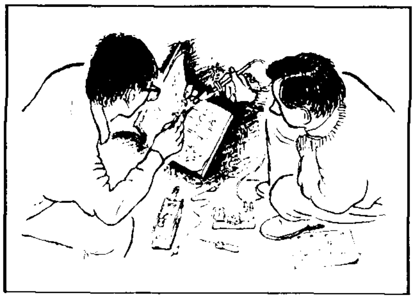
Soft-side zipper kits may be ordered by calling (800) 652-1234 or contacting Hand Tool Industries, Inc. 1933 Lake Street, Kent, Ohio 44240.

Circle #306 on Reader Service Card.

A waveguide flange drilling guide

It's not easy to lay out and drill the flange-hole pattern accurately for waveguide flanges. If you have my luck, the holes will tend to drift or migrate during drilling. You can hand file the holes with a round jeweler's file to bring them back to the proper positions, but the resulting fit is loose and/or sloppy. If you drill the holes right the first time, the next piece of waveguide will be properly positioned when you tighten the four mounting screws.

My drilling method is simple: use guide holes that have already been drilled accurately to guide your hand drill. You can use this technique for other flange sizes and connectors.

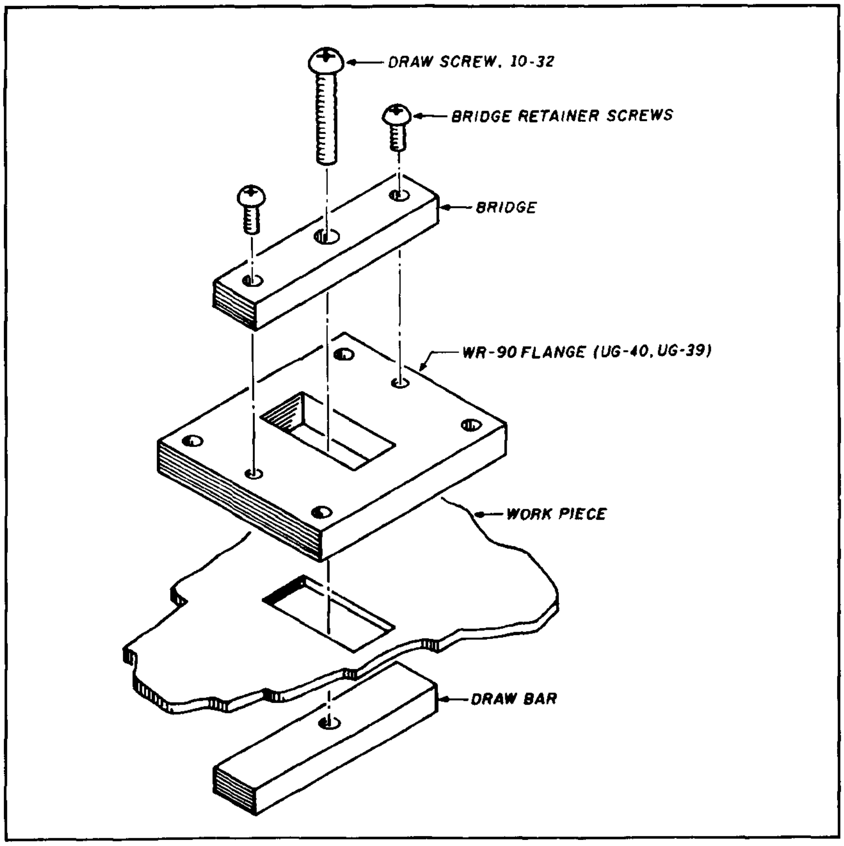


If you look at **Figure 1**, you'll see that the draw screw performs two jobs. It holds the assembly together and the drill guide motionless while you use the four flange holes as a pattern for drilling the holes in the work piece. I suggest using a 10-32 or 12-24 screw. The bridge bar must be narrow enough to allow easy inspection of the guide opening during attachment and alignment. Note that the bar is perpendicular to the long axis of the guide opening. The center hole is a clearance hole for the draw screw. The two outer holes pass two 6-32 mounting screws. You can use a single mounting screw or sweat solder the bar in place. The screws or solder serve only to hold the bar in a stable position while you position the drill guide. If you use screws, you must make matching threaded holes in the guide flange.

Nibble or machine the guide opening in the work piece before positioning the drill guide. Make sure the dimensions of the opening correspond to the *inside* dimensions of the waveguide. Center the drill guide over the guide opening and secure it by tightening the draw screw in the draw bar The tapped hole in the draw bar should match the draw screw. Make sure the draw bar is positioned free of the flange holes and is tightened securely before drilling the flange holes.

John M. Franke, WA4WDL

FIGURE 1



Mechanical diagram of the waveguide flange drilling jig.

50-MHz RF bridge

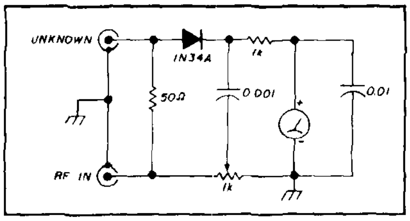
After the 1986 release of the 6-meter band to UK Amateurs, many UK hams found an RF bridge helpful for adjusting the gamma matches on their homebrew antennas.

The basic RF bridge[1] shown in **Figure 1** is difficult to use at the masthead, so I designed a self-contained unit to overcome this problem. Using the American Amateur's experience of the band,[2] I built a low-power transmitter drive source on the same pc board as the bridge. It operates with a 9-volt battery.

Circuit

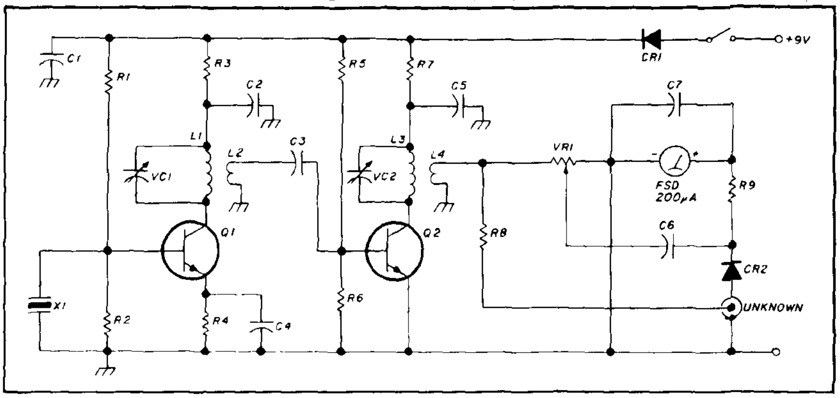
Figure 2 is the overall schematic. Q1 is an overtone oscillator that uses a 50-MHz third overtone crystal. The collector is tuned to 50 MHz by L1 and C1. The output signal from Q1 is link coupled via L2 and C3 to the base of Q2 — a class A amplifier stage with its collector tuned to 50 MHz by L3 and C2. The gain of this stage is quite high due to the grounded emitter, and the output should be approximately 40 mW. The output signal from Q2 is link coupled to the bridge circuit via L4.

FIGURE 1



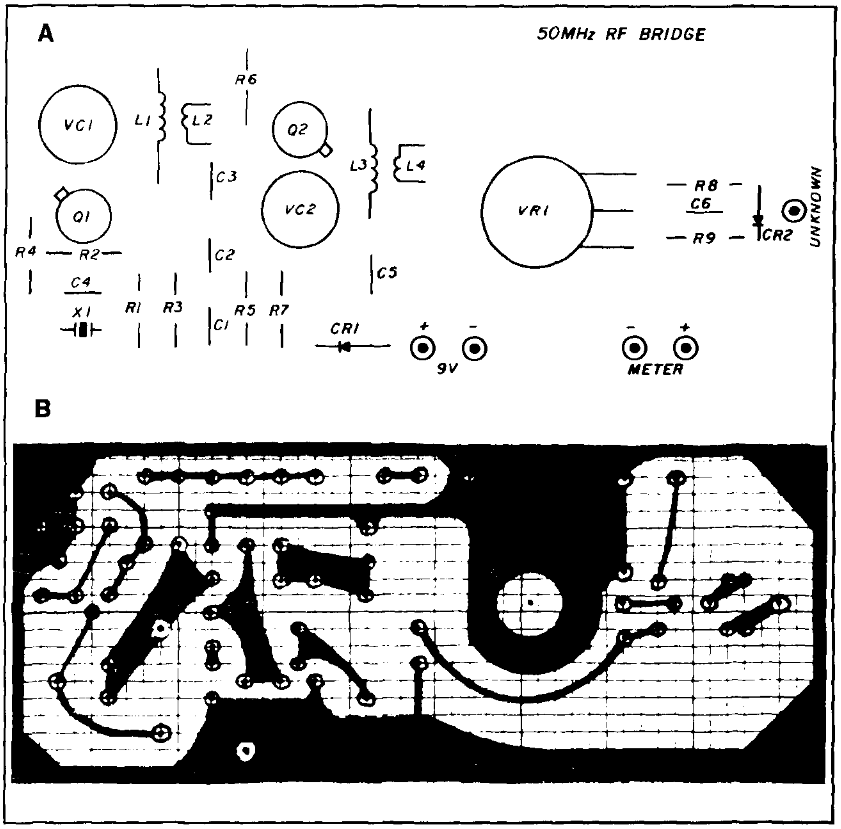
Schematic diagram of the basic RF bridge.

FIGURE 2



Overall schematic including the 50-MHz battery-operated transmitter.

FIGURE 3



Printed circuit and parts placement layouts for the RF bridge.

Construction

The unit is built on a single-sided 4-3/4" × 2" × 1/16" fiber-glass pc board (see Figure 3). Install the components on the board, leaving the potentiometer until last. Secure the pc board into the case using the threaded section of the potentiometer, as shown in Figure 4. You'll need to obtain a second nut for this potentiometer

PARTS LIST

RESISTORS
R1 10 k
R2 4.7 k
R3 100 ohms
R4 1 k
R5 680 ohms
R6 47 ohms
R7 100 ohms
R8 51 ohms
R9 1 k
VR1 1 k linear miniature potentiometer

SEMICONDUCTORS
Q1 BSX 20 (Europe) 2N2369 (USA)
Q2 BSX 20 (Europe) 2N2369 (USA)
CR1 1N4148
CR2 0A90 (Europe) 1N34A (USA)

COILS
L1 9 turns 22 swg (21 AWG) enameled wire, 1/4-inch diameter, 5/8-inch long
L2 2 turns thin insulated wire, 1/4-inch diameter, wound in the center of L1
L3 As L1
L4 As L2, wound in the center of L3

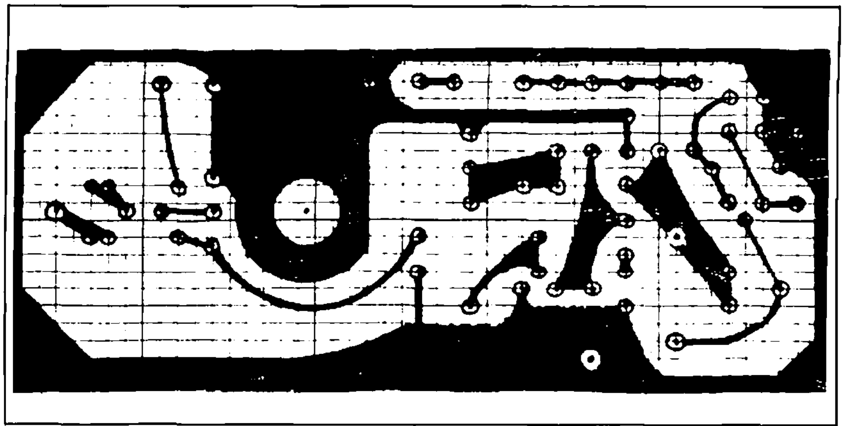
CAPACITORS
C1 0.01-μF ceramic disc
C2 0.01-μF ceramic disc
C3 0.01-μF ceramic disc
C4 15-pF ceramic disc
C5 0.01-μF ceramic disc
C6 0.001-μF ceramic disc
C7 0.01-μF ceramic disc
VC1 5 to 60-pF trimmer
VC2 5 to 60-pF trimmer

MISCELLANEOUS
X1 50-MHz third overtone series resonant crystal HC 18/U
Meter 200 μA FSD
SPST toggle switch
SO 239 socket
PCB terminal pins

Testing

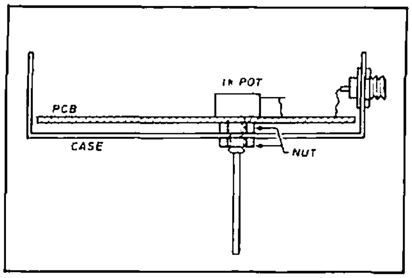
After you've completed the pc board, connect a 51 or 100-ohm resistor from the unknown terminal pin to the negative meter terminal pin. Connect a 9-volt supply to the battery terminal pins, making certain the polarity is correct. Adjust C1 and C2 for a 50-MHz output, using a digital frequency meter or an absorption wavemeter positioned near L1 and L3 in turn. When you have a 50-MHz output, connect the meter to the meter terminal pins and rotate R1 for a dip on the meter. If you get a dip, and all tests are

FIGURE 3C



Printed circuit board layout.

FIGURE 4



Details for mounting the pc board using the mounting nuts on the potentiometer.

satisfactory, remove the temporary resistor connected to the unknown terminal pin. You can now install the board in an RF-tight case or diecast box. I placed my prototype in an aluminum box 5-1/4″ × 4″ × 1-1/2″.

Calibration

To calibrate the bridge, you'll need a number of resistors and a plug to fit the socket. I used resistor values of 5, 10, 20, 30, 40, 50, 70, 75, 100, 150, 200, and 1000 ohms to calibrate the prototype.

Fit a white card scale to the front of the case and solder each resistor, in turn, into the plug. Connect the plug to the unknown socket and rotate R1 for a dip on the meter. When a dip is indicated, mark the scale with the value of the resistor used. The scale values should increase in counterclockwise sequence.

Conclusion

This RF bridge has simplified the adjustment of gamma matching sections and can be used to find the antenna tapping point on RF input coils of converters. You might also use it to find the input and output tapping points on bandpass filter coils.

For Amateurs in Region 1 (in countries where 4 meters can be used legally), the bridge can be modified by using a 70-MHz crystal, changing C4 to 10 pF, and retuning the resonant circuits.

The same design can be used for lower frequencies by changing the crystal, the resonant circuits, and C4. Capacitor C4, in the emitter of Q1, must have a reactance of 200 ohms at the crystal frequency.

REFERENCES

1. *ARRL Radio Amateurs VHF Manual*, 1968, page 284
2. *ARRL Solid-State Design for the Radio Amateur* 1977, page 30

A. R. Croft, G8CJM

Tom McMullen, W1SL

PART 2

VISUAL AIDS — LIGHT EMITTING DIODES

When transistors and integrated circuits began to dominate electronic equipment design in the seventies, the amount of power consumed by the equipment decreased rapidly. It got to the point where the power required to light the pilot lamps was greater than that needed to operate the equipment.

Technology continued to move forward, and a little lump of plastic with a couple of wires protruding from it went through a rapid development process. This device, called a light emitting diode (LED) gives us capabilities far beyond the simple incandescent lamp that it replaced. Let's look first at how it works, then at some of the ways it's being used.

Where does the light come from?

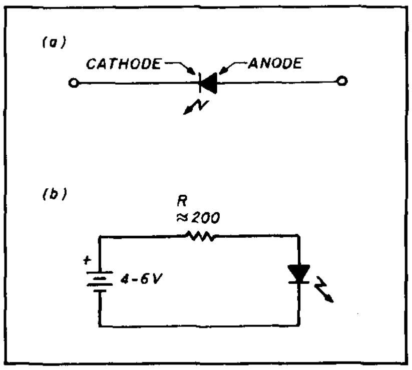
The LED is shown schematically in **Figure 1** as a diode with adjacent arrows pointing outward to indicate that it is emitting light. (Other devices exist that show the arrows pointing inward, indicating that they are responsive to light.) Some neat tricks of physics are used to obtain light from a small fragment of semiconductor material.

The key ingredients in an LED are usually gallium and arsenide. A diode made from these elements is sometimes referred to as a gallium-arsenide LED. (These same elements are used in Field-Effect Transistors, called GaAsFETS for Gallium Arsenide-Semiconductor Field-Effect Transistors.) The abbreviation LED is used almost universally today without regard for the elements that go into the semiconductor material.

Figure 2 shows a cross-section of a typical LED structure. There are many variations, depending on the requirements. Some are made flat to mount on pc boards, while others have wire leads that connect to associated circuitry.

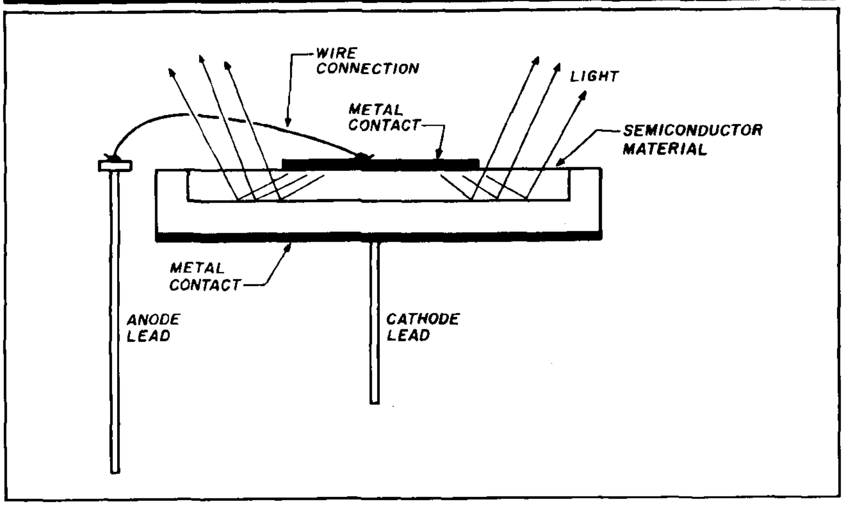
To understand how LEDs work, look again at basic semiconductor theory — electrons, holes, barriers, junctions, and all that. The same theory is at work in getting light out of a diode, getting a rectifier to turn AC into DC, or causing a transistor to amplify a signal. It's not really complicated. There's a junction between material with an excess of electrons (N type) and material with a scarcity of electrons (P type). Both types of material are created by impurities that were purposely introduced into the basic elements during manufacture. There is a region between these two materials where nothing much happens under normal circumstances. The extra electrons don't have enough energy to migrate to the other side, and the electron-scarce elements (often called "holes" or places where electrons could be) don't have enough energy to go the other way. There's a sort of trap zone in between, and any electron or hole that ventures into it gets stuck. To get things moving, a voltage must be applied across the junction. The voltage increases the "energy

FIGURE 1



A schematic symbol for a light emitting diode (LED) shown at (A). Most common LEDs work from a 5-volt supply, which must be applied through a current-limiting resistor of approximately 200 ohms (B).

FIGURE 2

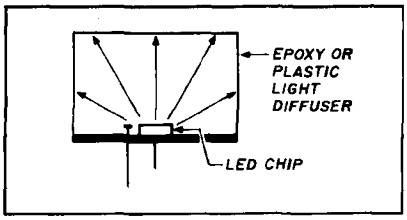


A cross-section view of LED structure. This whole assembly is usually placed in a plastic dome or cap which protects the assembly as well as diffusing the light for greater visibility.

level" of the electrons enough that they can move across the barrier to the "other side" where they combine with the "holes." As you might expect, when the free electron combines with a hole, each ceases to exist as a distinct entity. When they combine in this way, the excess energy they had must go somewhere, and it is emitted as "photons." The word photon can be roughly translated to mean "particles of light."

Of course, not all semiconductor diodes emit light. Many of them get rid of the excess energy as heat. Semiconductor manufacturers make sure that most of the energy is released as light by selecting the correct impurities to put into the material. That's where the materials gallium and arsenide come in, instead of the silicon and germanium used for rectifier or signal diodes. Some LEDs use a combination of gallium, arsenide, and phosphorus (called GaAsP semiconductor material), and others have some indium or antimony or other elements thrown in. Variations of these impurities can change the basic color (wavelength) of the light emitted and affect the efficiency of the LED. Currently available colors range from infrared to red, amber, and green. There are materials that emit light in the blue range, but not with great efficiency or brightness; research continues in that area.

FIGURE 3



A rectangular plastic enclosure for the LED element diffuses the light across its surface and can serve as a segment of a numeric readout as shown in *Figure 4*.

Putting the light to work

One of the earliest uses of the LED was as a replacement for the simple pilot light. It showed that a piece of equipment was on or off, or indicated some other function of the equipment by being illuminated or not.

Physically, an LED is very small; its size can work for or against its use. Because it is so small, you can place several LEDs close together for an array that takes up very little space. Most inexpensive incandescent lamps are between 1/4 and 3/8 inch across, so you are limited in the number of devices per inch. On the other hand, the LED's size limits the indicator's brightness and the width of the angle from which it can be viewed. This obstacle has been overcome in a couple of ways. One or more diodes can be made to illuminate a plastic lens that diffuses the light over a wider area, thus increasing visibility. Also, recent developments in diode technology have created LEDs with much greater light output.

The plastic lens or light diffuser can be shaped to create the exact effect desired — rectangular (see **Figure 3**), triangular, round, square, or diamond shaped. These devices are very useful when used in conjunction with different colors to "foolproof" a readout device, or help the user determine what action to take or see what is happening. An example is the arrow-shaped indicator on some Amateur equipment front panels that shows which VFO is being used. On some receivers, a green LED shows that a signal is being received; several green LEDs can show the signal strength. Some indicator panels that use green for receive indications also use red LEDs to show that the transmitter is on, and to give an indication of how much power is being transmitted. Infrared LEDs are commonly used in remote controls for television sets and video cassette players.

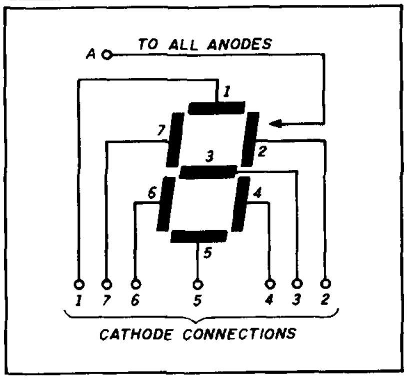
More than just light

You find LEDs in frequency readouts, digital panel meters, and many calculator displays. By placing one or more LEDs behind carefully shaped pieces of plastic, you can create letters or numbers. They are used in what is often called a seven-segment readout, shown in **Figure 4**. Some of these can be tiny, with three or four complete readouts on the top of an integrated circuit that plugs into a socket or mounts on a circuit board. Others can be quite large, like those in some clocks which have numbers 2 or 3 inches high.

An individual seven-segment readout device usually has eight connecting leads for power application — one common lead and one for each segment to be illuminated. You select the desired segment manually (with a switch) or (as is more often the case) with a special driver IC that interprets data from a computer, calculator chip, etc., and then illuminates the proper segment(s). For example, the number 3 can be created by applying a voltage between the common lead and the leads to segments 1, 2, 3, 4, and 5 shown in **Figure 4**. On many readout devices, there are also provisions for showing a period (decimal point), a colon (on clocks), and plus or minus signs.

Most readouts that produce numbers will also work for letters if a few compromises can be accepted. For example, in **Figure 4** a capital Q won't work, nor will an X of either case, but a lower case q will. With only slightly more complexity, a readout with diagonal segments can be made which will allow something close to a capital Q and will differentiate between a zero (0) and a capital O by placing a slash through the zero. It also allows creation of the letter X.

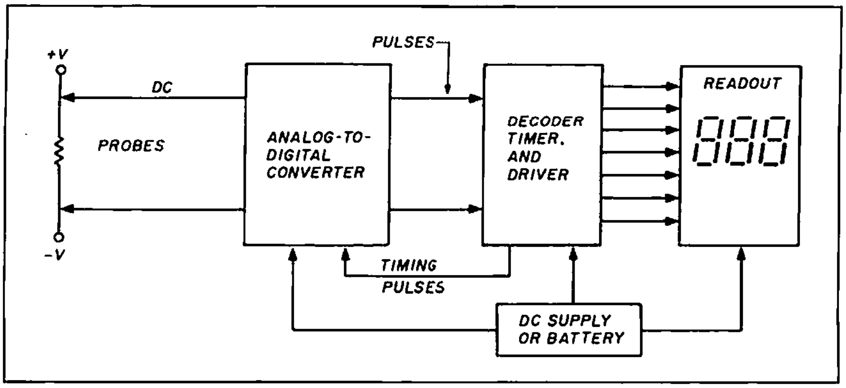
FIGURE 4



The common 7-segment LED readout can have a common anode connection and a connection to each individual cathode or it can be just the opposite, with all cathodes common. Other elements, such as a period, colon, or plus and minus symbols require additional LEDS and more connections.

Measuring a voltage (or current) with a conventional analog meter is a relatively simple process — you apply the voltage through appropriate resistors to the meter terminals, and the pointer moves in response. Its resting position is read against a scale to indicate the

FIGURE 5



A simplified block diagram of a digital voltmeter using 7-segment LED readouts. Multiple-readout panels can be found in many instruments including: frequency counters, clocks, calculators, watches, and many Amateur receivers.

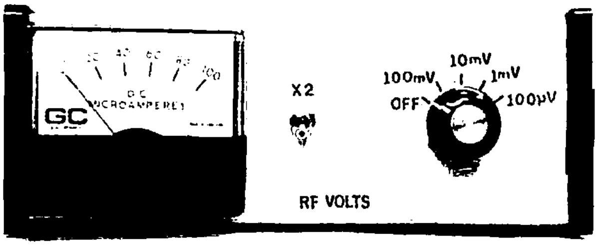
amplitude of the voltage being read. Doing the same thing with an oscilloscope (see last month's column) requires slightly more circuitry — power supplies, a sweep circuit, and an amplifier to deflect the electron beam proportionately to the voltage being measured.

A volt/ohm/milliammeter which uses LED indicators is also more complex, but not mysterious enough to scare you away. The circuit to drive the segments requires only low-voltage DC, like 5 or 12 volts, and current of a few milliamperes. However, these driver circuits require a digital input, and the quantities they are measuring are almost always DC (or analog). But this isn't a formidable task because there are specific integrated circuits that convert a given DC voltage into a digital output signal. These ICs are called analog-to-digital converters, or ADCs. (There are also digital-to-analog converters, or DACs, that do just the opposite.) The quantity to be measured is applied to the input of the ADC IC, which provides a series of pulses at its output to represent a number for that particular input. The LED driver IC then interprets this string of pulses and determines which segments to illuminate. Figure 5 is a simple block diagram of a digital voltmeter using these elements.

Using LEDs, you can reduce power consumption when you have several devices — like five or six readouts on a panel. By feeding the voltage to the LEDs in short pulses instead of DC, you can reduce the average current consumed by 50 percent or more. The trick is to make the pulses fast enough so that your eye doesn't know when the LEDs are off. This trait, called visual persistence, keeps you from seeing the 60-Hz flicker from devices like light bulbs and TV screens. **hr**

A SENSITIVE RF VOLTMETER

Read RF levels down into the microvolts



By John Pivnichny, N2DCH, 3824 Pembrooke Lane, Vestal, New York 13850

If you like experimenting with receivers, you need a way to measure low-level RF signals. This weekend project is a voltmeter with microvolt sensitivity. It covers a range of 20 μV to 200 mV, or an 80-dB range. You can use it to measure the output of RF and IF amplifiers, oscillators, crystal filters, and measuring bridges. An external attenuator[1,2] lets you read transmitter signal sources, like multiplier stages, mixers, and amplifiers.

The bandwidth is designed to cover from 0.5 MHz to over 30 MHz. It's also useful for comparison readings up to 100 MHz. Overall, I find it a very useful instrument to have on my construction bench.

Internal batteries supply the 20-mA current required at 15 volts DC, and provide isolation from AC line noise. The batteries also allow portable operation.

Circuit description

The schematic in Figure 1 shows a peak-reading diode voltmeter driven by two stages of amplification. I used a germanium diode 1N34A in the voltmeter circuit because it has a lower threshold voltage than the popular 1N914 silicon "glass diode" in many RF probe circuits. Those RF probes are intended for higher voltages than the undistorted ± 1 volt or so available from the MC1350P amplifier output.

A 100-μF capacitor provides a fairly large time constant. This results in satisfactory meter damping. The limited differential output voltage coupled with an overdamped meter prevents a lot of hard "needle pinning" when you select an incorrect range position, or make other errors. An SPST toggle switch selects additional series resistance. This X2 function gives some more overlap of the sensitivity ranges. The resistance values shown are correct for the 100-μA meter I chose (1500-ohm internal resistance).

Amplifier

I selected the MC1350P amplifier circuit because it's inexpensive and available from many sources. You can also use another, newer version — the MC1590. Although the schematic is identical, the MC1590 has a different set of pin assignments, so take care if you make a substitution.

The MC1350P is an RF/IF amplifier with a typical power gain of 40 dB, and a 60-dB AGC range. It has differential input and output. I used two stages in cascade. The first is driven as a single-ended input by bypassing the negative input to ground. The second stage is operated in true differential fashion. In the differential mode, there is an additional 6-dB gain and the available undistorted output swing is doubled.

Coupling capacitors of 4700 pF limit the low-frequency response below 500 kHz. I selected this value intentionally to keep out audio frequencies, including 60-Hz noise.

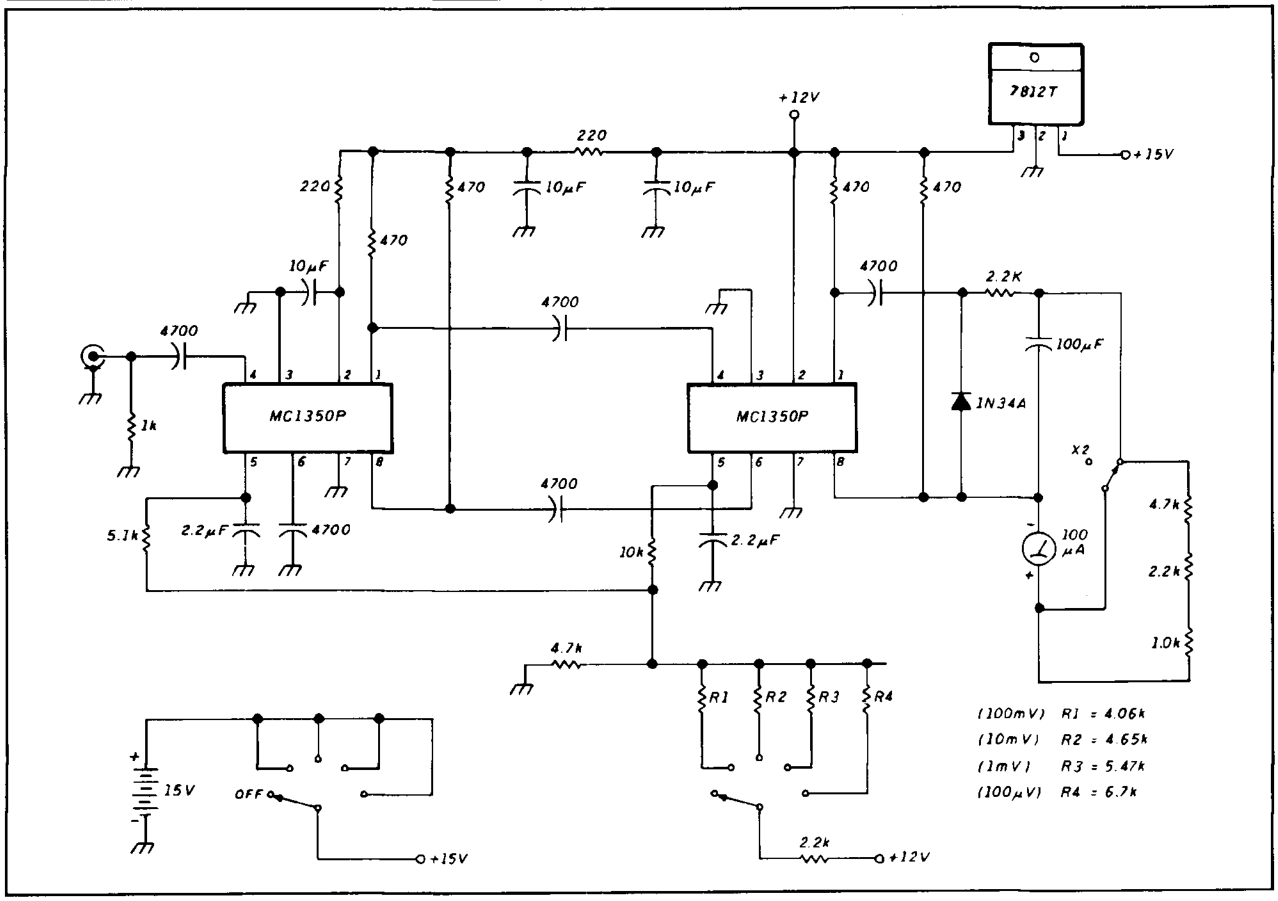
A popular voltage regulator keeps the supply at exactly 12 volts as the batteries wear down. It also provides a fixed voltage for the gain (AGC) control voltage dividers.

Voltage ranges

The MC1350P amplifier gain is controlled by applying a positive potential between 5 and 7 volts to pin no. 5. As the potential increases, the gain is reduced. When two stages are cascaded, it's important to decrease the gain of the first stage further. This prevents the first stage from overdriving the input of the second one. The application note[3] recommends series resistors of 5.1 k for the first stage and 10 k for the second one.

Actual full-scale voltage ranges are set by carefully selecting resistor values for the voltage dividers which feed these series resistors. I chose ranges of 100 mV, 10 mV, 1 mV, and 100 μV. The resistor values I used are shown on the schematic. These may vary somewhat based on the actual MC1350P parts used, as well as the meter internal resis-

FIGURE 1



Schematic of the RF voltmeter.

tance. The values shown are good starting points for the calibration described later in the article.

Input impedance is set by the 1-k resistor at the input connector. This is the largest value you may use if you want to have an unconditionally stable amplifier. You can reduce this to 50 ohms if you intend to use this voltmeter in 50-ohm systems only. I prefer the 1-k value; I shunt it with a 51-ohm resistor for 50-ohm systems, or a 240-ohm resistor for my 200-ohm crystal filters.

Construction

With the high gain and low signal levels present, I wanted no problems with instability. Consequently, I built the circuit on a 2" × 4" single-sided copper-clad board. Mount the components on the copper side and make ground connections directly to the copper ground plane, with essentially zero length ground connections. Pass component leads which don't connect to ground through a hole in the circuit board, countersunk on the copper side to form a clearance. Connect them on the bottom side as directly as possible. Usually the component lead will be long enough to reach its destination. Use short pieces of no. 30 gauge insulated wire to complete the connections in places where you need additional length. A hole location diagram and component placement sketch are shown in **Figures 2** and **3**.

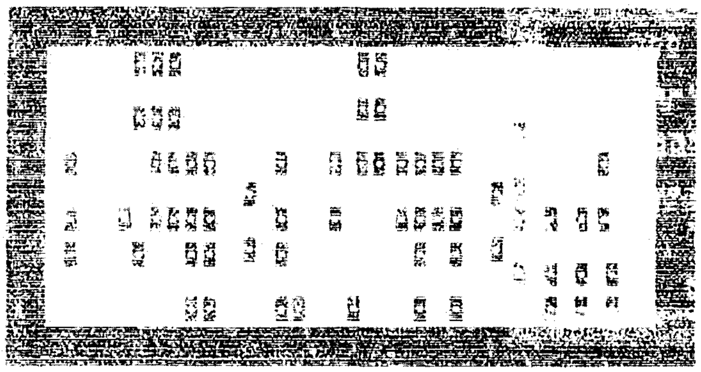
Next, mount the circuit board on the bottom of a metal case. Use two 4-40 sheet metal nuts as spacers on each of the mounting screws. This sandwiches the interconnection wires effectively between two ground planes, preventing coupling between wires which are about 1/4" apart. It also shields the components from the interconnection wires. As a result of the efforts I put into shielding and the care I took with the input impedance, I have never observed any instability or oscillation — even on the most sensitive range.

There is room inside the case for the battery holder. Hold it in place by clamping it to the bottom with a 3-1/8" length of 1/2" aluminum angle stock and two screws. Mount the meter and switches on the front panel. Add a BNC coax connector to the rear panel directly over the input connection to the circuit board. Use dry transfer lettering covered with clear acrylic to mark the switch positions. See **Photo A** for details.

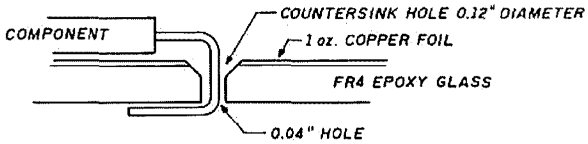
Calibration

I used the bootstrap procedure for calibration described by Hayward.[4] But I used a 200-ohm system; that is, I sol-

FIGURE 2

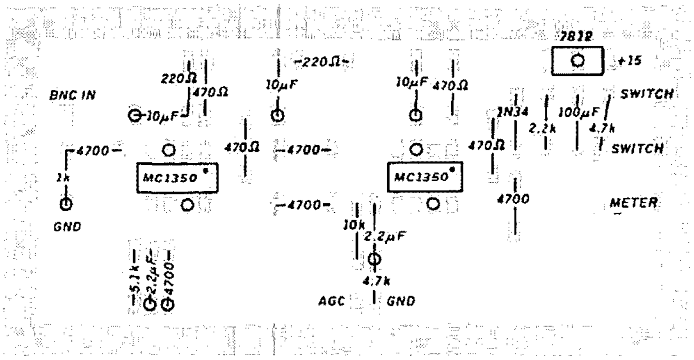


HOLE PATTERN - ACTUAL SIZE



Component mounting and actual size hole pattern guides.

FIGURE 3



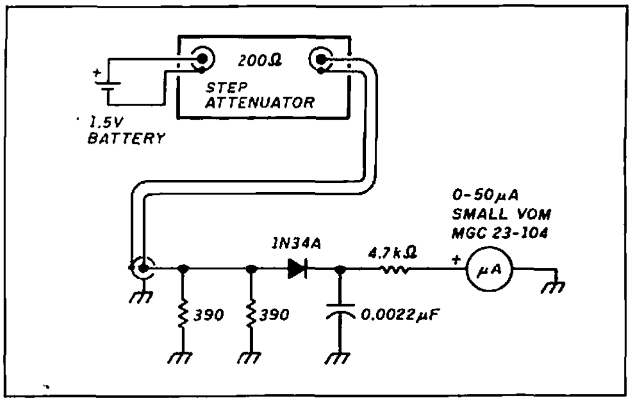
O- HOLE NOT COUNTERSUNK (GROUND CONNECTION)

Component location diagram.

PARTS LIST

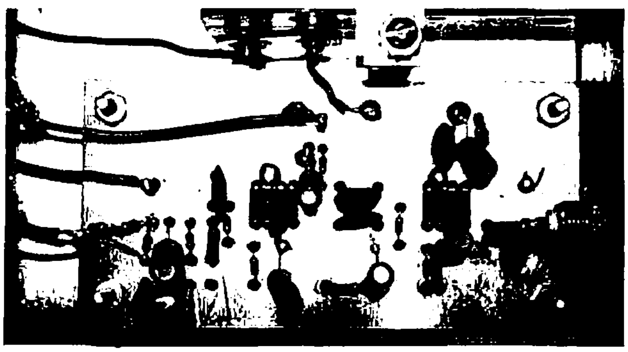
1 LM34OT-12	12-volt positive regulator — JimPak	3 10-μF	Electrolytic, 50 volts
1 JG-6	Cabinet 2-3/8" × 6-3/16" × 5-7/8" — Ten-Tec	2 2.2-μF	Electrolytic, 50 volts
1 BH-107	Battery holder for ten AA size — Caltronics	1 100-μF	Electrolytic, 20 volts
1 20-1111	0 to 100 microampere meter — GC Electronics	2 220 ohm	1/4 watt
1	SPST miniature toggle switch	4 470 ohm	1/4 watt
1	Rotary switch 2 pole, 6 position	2 1000 ohm	1/2 watt
1	Panel mount BNC connector	3 2.2 k	1/4 watt
10	Batteries — AA size	2 4.7 k	1/4 watt
1	2" × 4" single-sided circuit board	1 5.1 k	1/4 watt
2 MC1350P	IF amplifier	1 10 k	1/4 watt
1 1N34A	Diode — Radio Shack 276-1123		Dry transfer letters — Datak Corp K59B
5 4700-pF	Disc ceramic		Spray lacquer — Sherwin Williams 14-0969

FIGURE 4



Calibration circuit schematic.

PHOTO A



Circuit board details.

dered a 240-ohm resistor in parallel with the 1-k input resistor Using the simple circuit in Figure 4, I found that a 0.36-volt DC signal (step attenuator in the 12-dB position) read 30 mA on the meter. Then I injected RF from my 8-MHz oscillator into the same circuit, and read 36 mA with the attenuator in the 0-dB position.

$v_{peak} = 36/30 \times 0.36v = 0.432v$

The signal is 432/4 = 108 mV in the 12-dB position. I used this signal to calibrate the 100-mV scale. That is, I increased the resistor values for R1 until the meter read 108 mV. Then I connected a number of fixed resistors in series, and soldered them in place.

Next, I increased the signal level by adjusting the voltage on my oscillator circuit until it read 100 mV with the attenuator in the 20-dB position. I switched the attenuator to the 40-dB position and the voltmeter to the 10-mV range. I selected resistors for R2 for a full-scale reading on this range. I performed this procedure two more times until all ranges were calibrated, but with error accumulation at each step.

Other uses

This meter has many uses around the shack besides reading low-level RF signals. Is that new oscillator circuit oscillating? Just connect a few turns of wire at the end of a coax, and connect the other end to the meter. Hold the loop near the oscillator circuit for a quick check for RF. Can't hear that crystal calibrator? Is it working? Hook its output to the RF voltmeter and see. What's the signal level on your TV cable? Mine reads 600 μV with a 200-ohm load before it's split two ways going to my two television receivers. A paper clip inserted in the BNC jack is enough of an antenna to pick up the signal from my grid-dip meter when it's several inches away.

Next to my frequency counter, this is the most useful homebrew project I've ever built. Try one for your next weekend project.

dB Chart. Many Amateurs have difficulty converting from millivolts to dBm power figures. Remember that 0dBm is usually meant to represent a power of 1 mW into a 50-ohm load. See the chart below for rapid conversion from one set of units to the other (for 50-ohm systems).

The numbers below show the approximate ranges of this meter and the (more accurate and linear) one described by G4COL.[5]

	Power		Millivolts	
	dBm	milliwatts	RMS	peak
G4COL's meter				
	20	100	2240	3170
	10	10	707	1000
	0	1	224	317
	−10	0.1	70.7	100
N2DCH's meter				
	−10	0.1	70.7	100
	−20	0.01	22.4	31.7
	−30	0.001	7.07	10
	−40	0.0001	2.24	3.17
	−50	0.00001	0.707	1.0
	−60	0.000001	0.224	0.317
	−70	0.0000001	0.071	0.100
	−80	0.00000001	0.022	0.032
	−90	0.000000001	0.007	0.010

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1 John Pivnichny, N2DCH, "High-Impedance Rotary Step Attenuator," *Ham Radio*, February 1989, page 24.
2 Bob Shriner, WA0UZO and Paul K. Pagel, N1FB, "A Step Attenuator You Can Build," *QST*, September 1982, page 11.
3 Brent Trout, "A High Gain Integrated Circuit RF/IF Amplifier with Wide Range AGC," Motorola Application Note AN 513, Motorola Semiconductor Products, Inc.
4 Wes Hayward, W7ZOI, "Defining and Measuring Receiver Dynamic Range," *QST*, July 1975, page 15.
5 Ian Braithwaite, G4COL, "An RF Voltmeter," *Ham Radio*, November 1987, page 65.

A HIGH-PERFORMANCE 2-METER TRANSVERTER

Modular approach makes construction and modification easy

By Bob Lombardi, WB4EHS, 1874 Palmer Drive, Melbourne, Florida 32935

It seems that many VHF/UHF enthusiasts say they became interested in this part of the spectrum after having worked just about all of the DX available on HF. This wasn't the case for me. The possibilities of 2-meter operation appealed to me on their own merits. There is OSCAR, moonbounce, meteor scatter, SSB, CW, and a host of propagation modes to explore.

My interest in these modes of communication led me to review their requirements. I realized that commercial rigs available at the time didn't have the two main features I was looking for — a low noise figure and a selectable CW filter. Like many before me, I decided to build a transverter for my HF rig. These were my design goals:

- low noise figure, in keeping with the state of the art;
- output power in the range of 5 watts, with excellent linearity (third-order IMD at least 30 dB down);
- good rejection of a nearby NOAA weather radio relay (at least 40 dB down);
- moderate gain (enough to overcome the front end noise of the HF rig);
- good dynamic range.

I adopted a modular design approach advocated by Joe Reisert, W1JR, and others. I like this design because it gives me the ability to get sections working and tied together quickly. This, in turn, makes the project seem less like a constant uphill battle. Also, the modular method with its replaceable sections is a great benefit when you come up with a better design. The block diagram of the transverter appears in **Figure 1**.

Receive strip

The receive side input (**Figure 2**) is a GaAsFET low-noise amplifier (LNA) that uses a circuit similar to Reisert's[1] and to those in general FET applications notes. The device is a single gate MGF-1402 made by Mitsubishi; it's available from several sources.* The 10-k resistor on the input bleeds off static buildup. Any value around 10 k will work, as long as you use a carbon composition resistor. (I had a persistent and elusive oscillation; it was caused by the metal film resistor I was using!) I used diodes around the regulator to protect against regulator latch-up or inductive spikes from the T/R relay. The amplifier had a noise figure of under 0.75 dB and a gain of 23 dB, as measured on an Ailtech noise figure meter and HP network analyzer.

The filter (shown in **Figure 3**) was described in an earlier article.[2] I wanted the filter to be narrowband enough to pass all 4 MHz of the band, and still provide over 40 dB of rejection at 162.55 MHz. It provides nearly 55 dB, at a cost of about 5 dB of insertion loss. At this point, however, there was gain to burn to meet the design goals of about 10 dB of gain in the complete transverter.

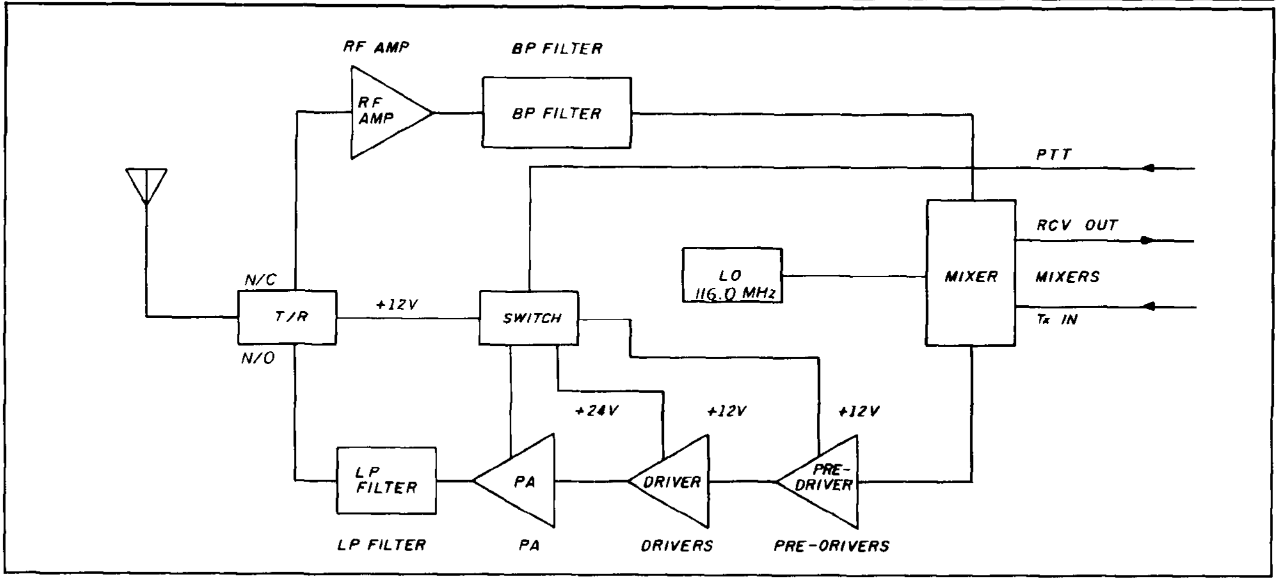
A 116-MHz overtone crystal oscillator provides the LO function for both sides of the transverter (**Figure 4**). The oscillator is a common base design, largely based on Reisert.[3] The output was measured at +13 dBm, allowing the use of a two-way power splitter to provide LO to both mixers.

The receive mixer is a Mini-Circuits SRA-1000 (see **Figure 5**). It is essentially the same as their SRA-1 in this application. The IF output goes into a diplexer and 24 to 34-MHz bandpass filter. In band, the diplexer (the parallel-resonant circuit and 51-ohm resistor) presents an open circuit, and no signal flows in the resistor. As the frequency changes the reactive components tend to short out the tank circuit, allowing signal to flow into the termination and to ground. The mixer sees the 51-ohm resistor at these frequencies.

The receiver input stage is largely responsible for determining the system noise figure, and the noise figure is degraded by any losses in front of it. If you're new to the field of low-noise design, this explains what must seem like the unconventional design of the transverter; i.e., the amplifier ahead of the filter. (This is a common design technique in microwave receiver

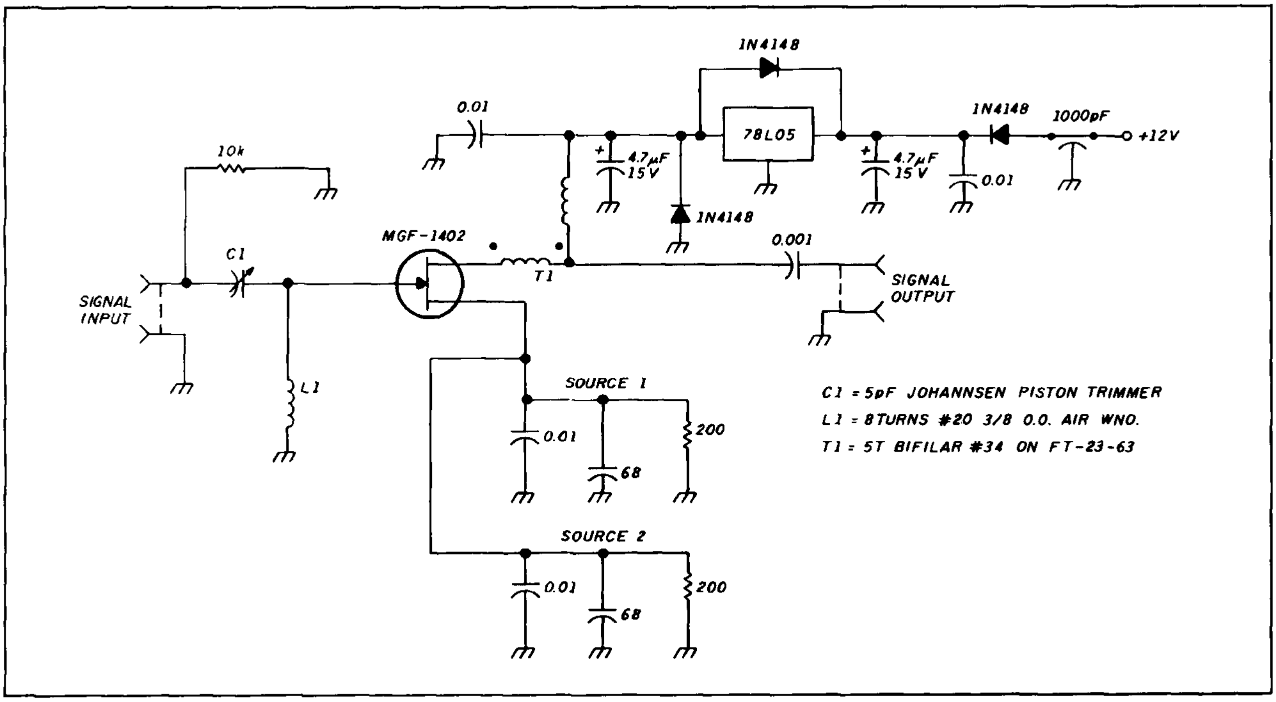
*See parts sources at the end of the article. *Ed.*

FIGURE 1



Block diagram of the complete transverter.

FIGURE 2

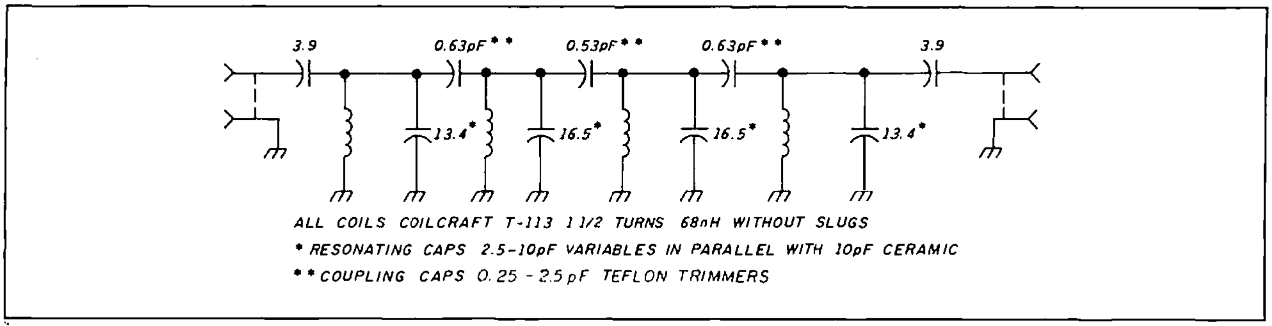


Schematic of the receive input RF amplifier.

design, like TVROs.) To minimize the effects of losses in front of the amp, I used foam-flex (hardline) coax as the feedline, with short flexible jumpers of RG-214/U where required.

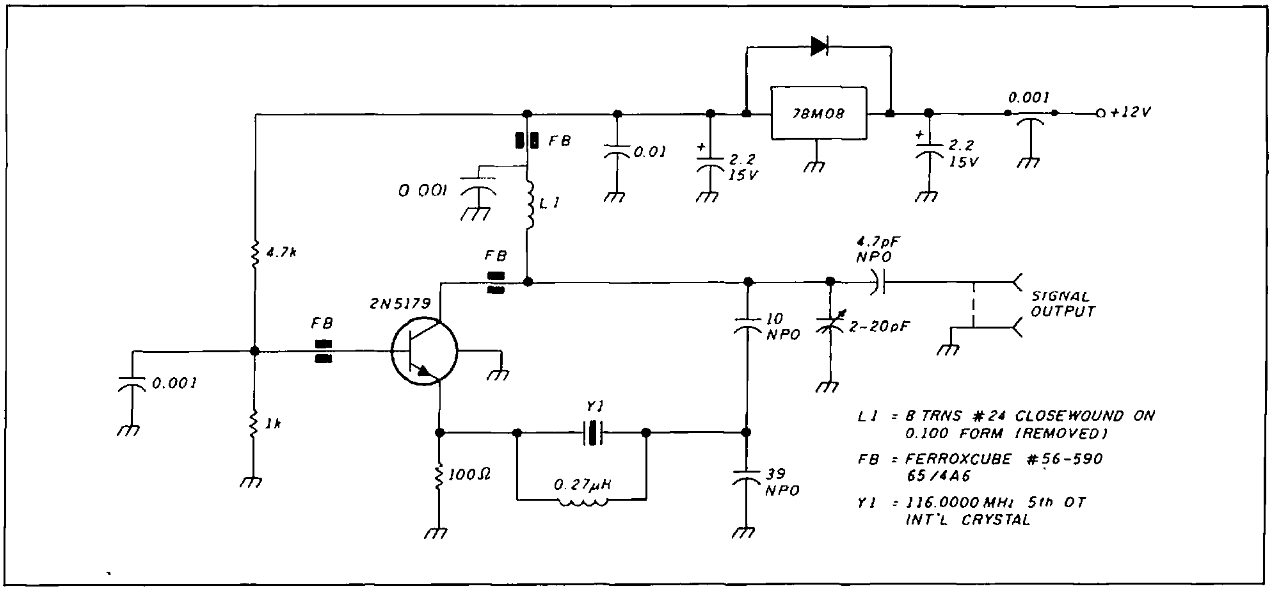
Other hams have told me on the air that my low noise figure is unnecessary in 2-meter SSB because ground noise predominates. While this maybe true, my idea all along was that receiver noise shouldn't be a limiting factor if I wanted to swing my antennas up for OSCAR — or anything else I might try. When you add that to the high intercept point of the GaAs-FET front end, and the resulting improvement in dynamic

FIGURE 3



Details of the BP (bandpass) filter on the receive line.

FIGURE 4



Local oscillator using a 116-MHz overtone crystal.

Parts list

CAPACITORS

Electrolytic or tantalum

1.5 μF/15 volts	*1 each*
2.2 μF/15 volts	*1 Radio Shack 272-1435*
4.7 μF/15 volts	*3 272-1024*
10 μF/35 volts	*1 272-1025*
330 μF/16 volts	*1 272-1030 (470 μF)*

Ceramic, monolithic dipped, 50 volts (Z5U or X7R)

68 pF	*2*
470 pF	*1*
0.001 μF	*20*
0.01 μF	*10*
0.1 μF	*1*

Ceramic, monolithic dipped, 50 volts (COG or NPO)

3.9 pF	*4*
4.7 pF	*1*
10 pF	*8*
27 pF	*1*
39 pF	*1*
47 pF	*2*
270 pF	*2*

Trimmers—all values in pF

0.25-2.5 Teflon	*4 BP filters*
0.5-5 glass/air	*1 GaAsFET amp*
1-5 pF ceramic	*5*
2-20 ceramic	*5*
2-8 mica	*2 PA*
2.4-50 mica	*2 PA*
2.5-10 ceramic	*5*
9-35 ceramic	*4*
5.5-18	*1**

**Most of these came from my junkbox, the result of years of hamfest buying. Try Communications Concepts, Inc., and other. Some of these could be made into more parts of one value.*

RESISTORS

1/4-watt carbon composition, 5 percent

51 ohm	*1*
100 ohm	*1*
200 ohm	*2*
1 k	*2*
1.5 k	*1*
4.7 k	*1*
5.6 k	*1*
10 k	*4*
100 k	*1*

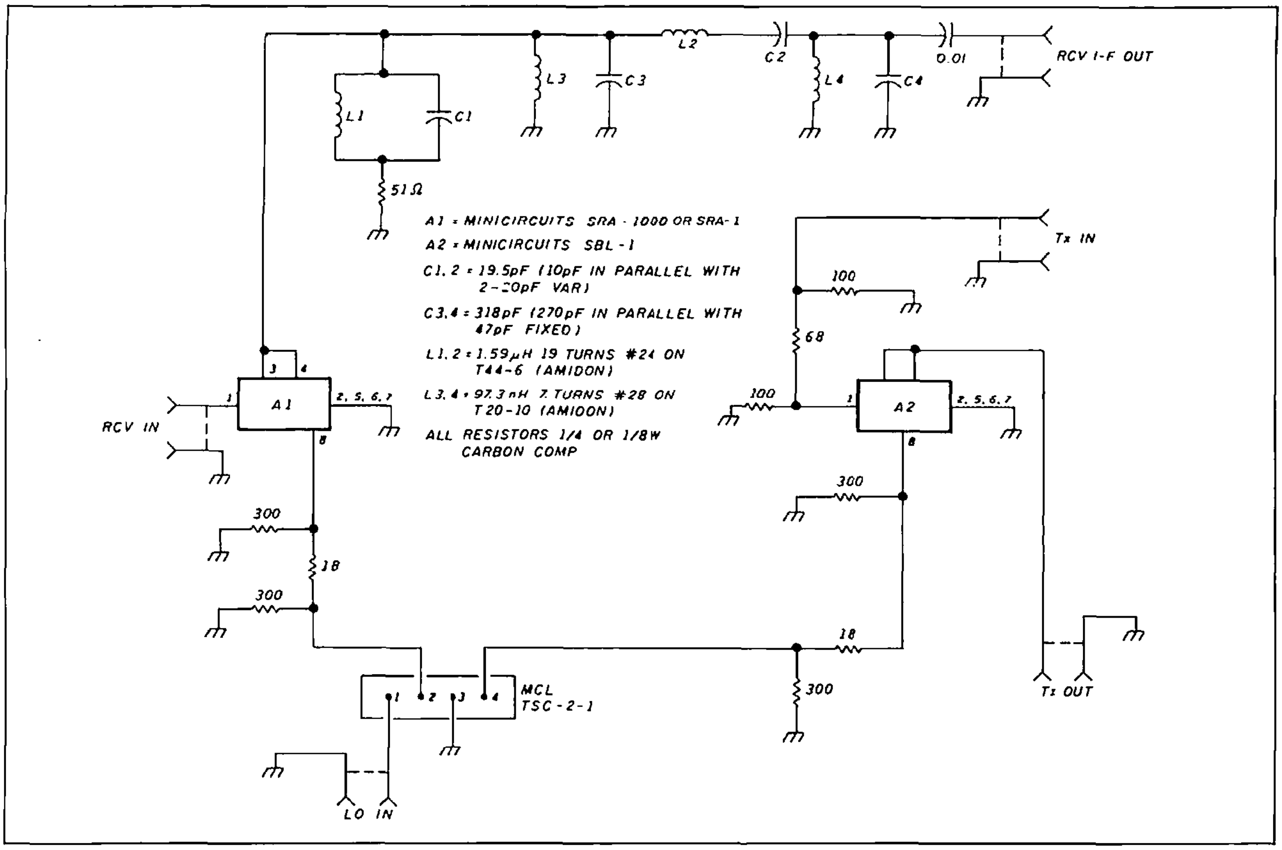
1/2-watt carbon composition, 5 percent

100 ohm	*2*
750 ohm	*1*

1-watt carbon composition, 5 percent

62 ohm	*2*
68 ohm	*1*

FIGURE 5



Receive and transmit mixer schematic.

2-watt carbon composition
Any value over 100 k (used as coil form)
1/8-watt carbon composition, 5 percent

18 ohm	*2*
300 ohm	*4*
68 ohm	*1*
100 ohm	*2*

SEMICONDUCTORS

Diodes

1N4148 general purpose	*6 (widely available)*
1N4004 rectifier	*1*
1N757 9-volt zener	*1*
1N751 5-volt zener	*1*

Transistors

2N2222 NPN	*1*
2N3553 NPN	*1 RF Parts Company*
2N5109 NPN	*1 RF Parts Company*
2N5179 NPN	*1 RF Parts Company*
MGF-1402 GaAsFET	*1 RF Parts Company*
MRF-134 powerFET	*1 RF Parts Company*

OTHERS

MWA-130 amplifier modules	*2 Communications Concepts*
78L05 5-volt regulator	*1 (widely available)*
78L08 or 78M08 8-volt regulator	*1 (widely available)*
LM-311 comparator	*1 (widely available)*

MISCELLANEOUS PARTS

Ferrites

FT-23-63	*1 Amidon*
Beads, Ferroxcube type 4A6	*4 Amidon (cross-reference)*
Two-hole balun (for RFC on driver assembly)	
BLN 43-2402	*3 Amidon*
Ferroxcube VK200-19/4B	*1 Amidon (cross-reference)*

TOROIDS

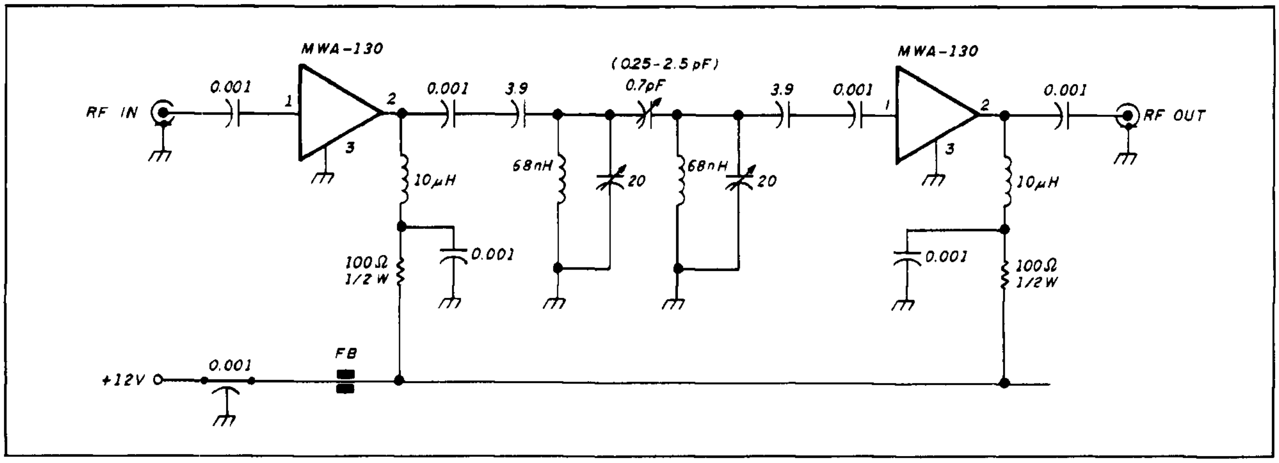
T44-6	*2 Amidon*
T20-10	*2 Amidon*

Note: The exact ferrite bead used in most cases isn't critical. It should present several microhenries of inductance at the operating frequency.

OTHER PARTS

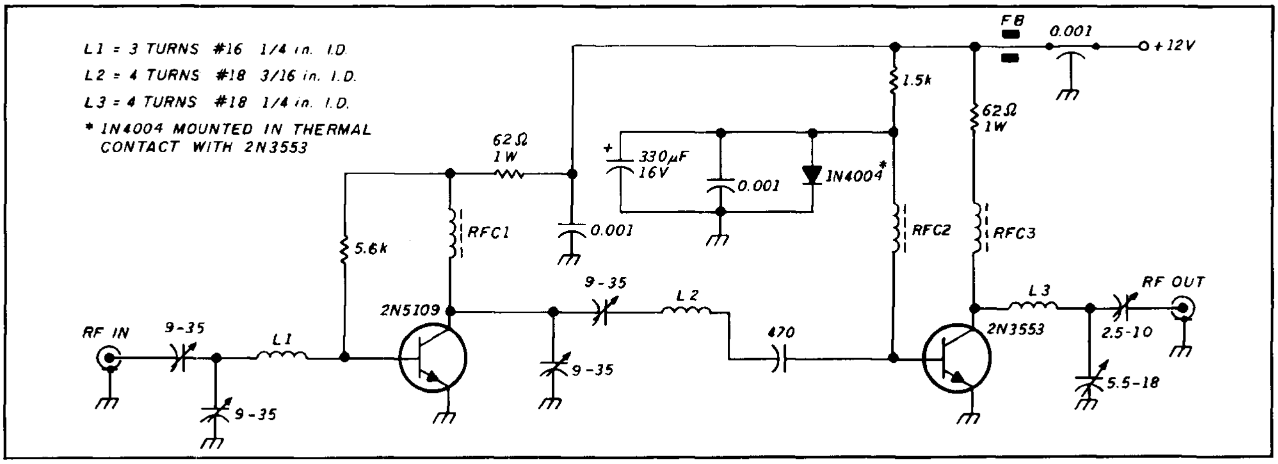
SBL-1 mixer	*1 Mini-Circuits, others*
SRA-1	*1*
TSC-2-1 power splitter	*1 Mini-Circuits, others*
116-MHz fifth overtone crystal	*1 ICM*
5-k multiturn pot	*1 Radio Shack*
T/R power switch relay 12 volt	*1 Radio Shack*
T/R coaxial relay 12 volt	*1 Communications Concepts*
RF coaxial connectors	*15 SMA female (as required)*
Coaxial jumpers	*(as required)*
Boxes	*(as required)*
Feedthrough capacitors	*0.001 μF 50 volts (as required, 1 per box)*
10μH molded chokes	*2*

FIGURE 6



Transmit predriver schematic.

FIGURE 7



Driver chain schematic. RFC 1-4 = 4 turns of no. 20 wire through a two-hole ferrite balun. Amidon no. BLN 43-2402.

range, the GaAsFET still seems the most logical choice.

My initial test of the receive side yielded good results. While conducting tests with WA4GHK (15 miles south), it was easy to copy K4DZP in Miami (over 160 miles south) — despite my makeshift indoor antenna!

Transmit chain

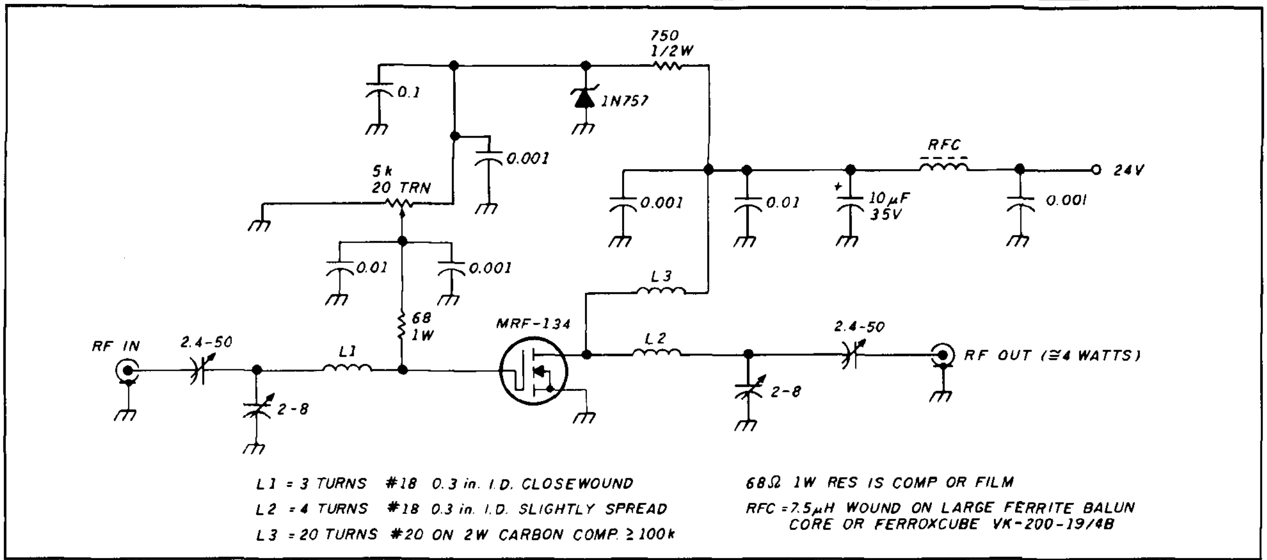
The transmit portion of the transverter presents its own problems; the biggest is linearity. A rule of thumb for diode ring mixers (like the SBL-1 used here) is to have the input signal at least 10 dB below the LO for best linearity (see **Figure 5**). Because one of my design goals was to achieve very good linearity from the transmitter, the first thing I did was pad the input drive (+3 dBm) from my HF rig. The resulting level was about −7 dBm, 14 dB lower than the LO drive. Since all the pads were made with the closest value resistors, and the mixer itself contributes loss, I measured the conversion loss of the transmit mixer. It was 17.7 dB.

The pre-driver stage in **Figure 6** is suppposed to recover all of the signal lost in the conversion, provide enough filtering to remove significant power on the image frequency, and reduce LO feedthrough. I used MWA-130 amplifiers, modular 50-ohm in-and-out devices in TO-5 cans, because they are easy to use and were available on a surplus board that I scavenged. The power out at this point is 4 mW (+6 dBm).

The actual drivers are two transistors, a 2N5109 and a 2N3553 (see **Figure 7**). The first device is a well-known VHF linear transistor; the second is a 28-volt, TO-5 can device capable of 2 watts if run class C. This was originally to have been a three-transistor strip with 1 watt out from a third 2N3553, but I was never able to get them to more than 500 mW and still remain linear with a 12-volt supply. I tried many variations of bias circuits, matching networks, and pc layouts. The two-device strip I settled on produces 18 dB of gain, or about 250 mW out.

The final amp is a Motorola MRF-134 TMOS powerFET that delivers just over 4 watts out and a clean, linear signal (third-order intermod down just over 30 dB). See **Figure 8** for details.

FIGURE 8



Final amplifier using an MRF-134.

All design decisions are tradeoffs. For example, using the MRF-134 created the need for a small 24-volt supply — but I gained advantages in other areas. First, the FET is guaranteed to deliver rated power into a 30:1 VSWR at any phase angle (no delicate device here!); second, it's capable of more gain in one package than a bipolar; and last, it worked the first time I tried it — a very enjoyable experience after my trials and tribulations with the '3553s.

The circuit is taken largely from the *Motorola RF Data Book* applications note.[4] Component changes are based on availability and personal preferences. In any RF power amplifier it's essential to keep the ground leads of the device as close as possible to ground on the board. I connected top and bottom foil with a strip of copper shim stock at the point where the source leads leave the device package. The FET itself is on an extremely overrated heat sink; after extended key down periods everything remains at ambient temperature.

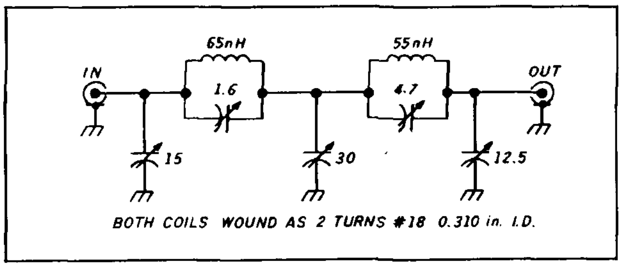
The output filter in **Figure 9** is an elliptical low-pass design. The two parallel resonant circuits are tuned to 313 and 487 MHz with a grid-dip meter; the other caps are adjusted for minimum insertion loss while you watch output power on a wattmeter. My version had a measured insertion loss of under 0.2 dB.

I used a simple comparator on the PTT line from the HF rig to do the T/R switching (see **Figure 10**). The relay is DPDT. It switches 12 and 24 volts to the transmit amplifiers and 12 volts to the antenna relay (a Dow-Key relay I picked up at a local hamfest). The relay provides over 40 dB of isolation during transmit; the GaAsFET sees −4 dBm, well within its capabilities. (I leave it powered on continuously.) This relay should be adequate at power levels of up to 100 watts.

Construction and alignment

This is a sophisticated project and you'll need building experience. If you've had experience with other RF circuitry, you'll find it presents few special challenges. I used pc boards

FIGURE 9



Schematic of the transmit LPF (low pass filter).

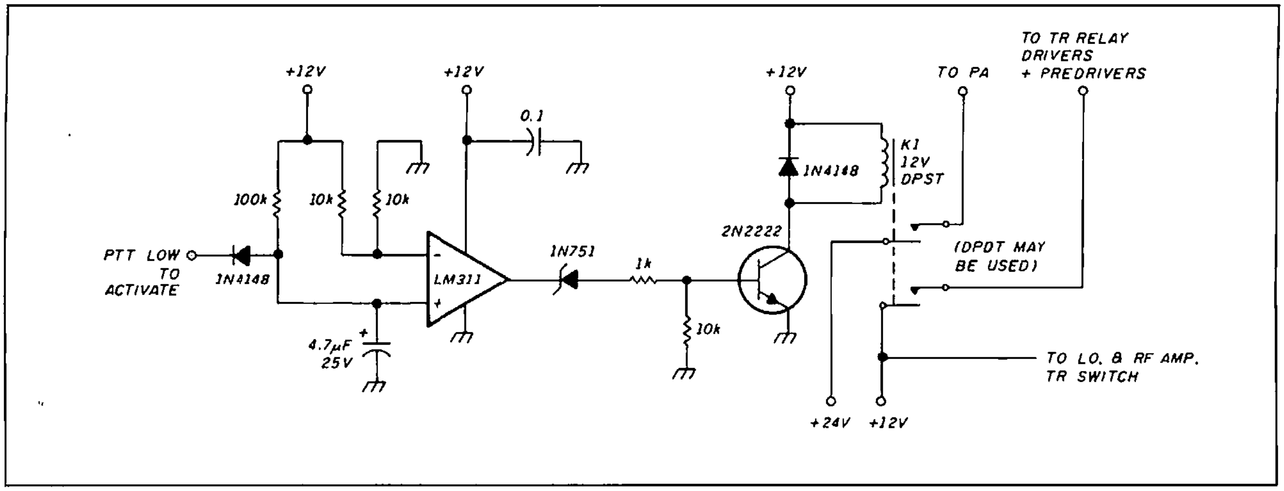
for the GaAsFET RF amplifier, filters, and all transmit stages. The LO, mixers, and the T/R switching boards are built "dead bug" style; they function quite well that way. If you are an experienced builder who uses point-to-point techniques at these frequencies, you may want to use that method. I used SMA connectors on small-diameter coax (RG-188) for signal interconnects. You may prefer to use BNCs. Likewise, I used pc board material for housing circuits — you may prefer commercially made enclosures.

I've already mentioned the need to keep grounds short on the final amplifier; the same holds true tor the driver stages. This is the strongest argument for using pc boards for these stages. The emitters of the driver transistors are grounded immediately, with minimal lead length.

There are no "peculiarities" of alignment. Align the filters separately, tuning them as desired. It's best to align the transmit stages with a spectrum analyzer. Tune the drivers for best output while observing third-order intermod. This will not occur at maximum power out. The same applies to the final amplifier.

Ideally, the GaAsFET should be aligned with noise figure instrumentation. If that isn't available, tune for maximum noise level by ear, and then detune slightly. The optimum noise fig-

FIGURE 10



T/R switch schematic.

ure match isn't far from max gain, but that's about as quantitative as I can get.

Performance

On-the-air results have been good. I actually used the transverter for quite a while at the 250-mW level, and surprised myself by working most of peninsular Florida. I made some of my best contacts with an indoor antenna and the pieces of my project spread across my desk. Moving up to 4 watts put me within 3 dB of the mainstream of off-the-shelf 2-meter SSB rigs (that's about half of one S-unit), and to a level that could be used with commercial amplifiers. It also netted me contacts with live southeastern states using a small antenna at rooftop height.

I'd like to thank Jim Hagan, WA4GHK, for his part in the conceptual design of this circuit and for helping me with on-the-air tests. hr

Parts sources

Digi-Key
701 Brooks Avenue South, PO Box 677,
Thief River Falls, Minnesota 56701-0677
A broad line of passives, semiconductors, and tools

Mini-Circuits
PO Box 350166 Brooklyn New York 11235-0003
Mixers, splitters, hybrids, etc. will sell to individuals

Amidon Associates
12033 Otsego Street, North Hollywood, California 91607
Toroids, ferrites, inductive components

Communications Concepts Inc
121 Brown Street, Dayton, Ohio 45402
RF parts and kits, hard to find trimmers, chip caps, transistors, ATV parts

RF Parts
1320 Grand Avenue, San Marcos, California 92069
RF power devices, GaAsFETS, and many other transistors

REFERENCES

1 Joe Reisert, W1JR, "Low-Noise GaAsFET Technology," *Ham Radio*, December 1984, pages 99-112
2 Bob Lombardi, WB4EHS, "Build Narrowband Filters," *Ham Radio*, March 1986, pages 18-21
3 Joe Reisert, W1JR, "High Dynamic Range on 2 Meters," *Ham Radio*, November 1985, pages 54-64
4 Technical Staff ed, *Motorola RF Device Data Book*, Arizona, 1986

Practically Speaking

Joseph J. Carr, K4IPV

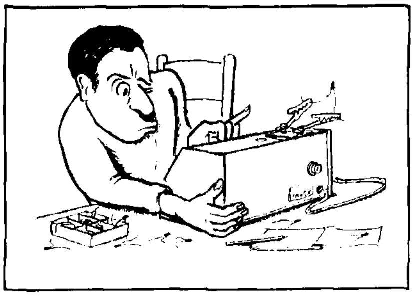
MORE DIGITALLY GENERATED SAWTOOTH, PLUS TRIANGLE WAVES

I've dealt with methods for generating sawtooth waveforms, and discussed them in this column on several occasions. I became interested in this topic quite a while ago — right after I built the Science Workshop's "Poor Man's Spectrum Analyzer." The project uses a sawtooth waveform to sweep the DC tuning control voltage of a varactor-tuned TV front end. In an article reviewing the analyzer, I mentioned that it was possible to build a digitally generated sawtooth waveform that was quite a bit better than the op amp version used in the original project. The response was staggering; I'm still receiving requests for the circuit. I've already published one version of the circuit in this column. This month I'm going to take a look at an updated version that allows control over sweep width, and superimposes the sawtooth on top of a DC level that sets the center frequency of the spectrum analyzer.

I'll also discuss an even newer version of the circuit that allows several options including negative-going sawtooth, positive-going sawtooth, and a triangle wave. In all three cases, the waveform is generated by applying the output of a binary counter to the input of a digital-to-analog converter (DAC).

The circuit for the original digitally synthesized sawtooth generator is shown in **Figure 1**. The heart of this circuit is IC1, a DAC0806 eight-bit DAC. This converter is an inexpensive IC, based on the MC-1408 family of DACs. I selected the DAC0806 because it's appropriate to the application and easily available through mail-order sources like Jameco Electronics, or in blister packs through Jameco's local distributor line — Jim-Paks.

A "multiplying" DAC like the DAC0806 produces an output current that is proportional to: **a)** the reference



voltage or current, and **b)** the binary word applied to the digital inputs. The controlling function for the DAC selected for this article is:

$$I_o = I_{ref} \times \frac{A}{256} \qquad \textbf{(1)}$$

Where:

I_o is the output current from pin no. 4

I_{ref} is the reference current applied to pin no. 14

A is the decimal value of the binary word applied to the eight binary inputs (pins 5 through 12)

The reference current is found from Ohm's law. It is the quotient of the reference voltage and the series resistor at pin no. 14. In data acquisition systems, where the DAC is most used, the reference voltage is a precision, regulated potential. But in this case you don't need the precision, so use the V+ power supply as the reference voltage. This means the reference current is +12 volts DC/R1. With the value of R1 shown (6800 ohms), I_{ref} is 0.0018 A, or 1.8 mA. Values from 500 μA to 2 mA are permissable with this device. If you elect to change the reference current, be sure to keep R1 equal to R2.

The reference current sets the maximum value of output current I_o. When a full-scale binary word (11111111) is applied to the binary inputs, output current I_o is:

$$I_o = (1.8\ mA) \times \frac{255}{256} \qquad \textbf{(2)}$$

$$I_o = (1.8\ mA) \times (0.996)$$
$$I_o = 1.78\ mA$$

Because the DAC0806 is a current output DAC, you must use an op amp current-to-voltage converter to make a sawtooth voltage function. Such a circuit is an ordinary inverting follower without an input resistor. The output voltage (V_o) will rise to a value of $I_o \times$ R5.

The actual output waveform from the circuit of **Figure 1** is "staircased" in binary steps equal to the least significant bit (LSB) current of IC1 (or the LSB voltage of V_o). The LSB voltage is the smallest step change in output potential caused by flipping the least significant bit (B1) either from 0 to 1, or 1 to 0. The reason you don't see the steps in **Photo A** is that the frequency response of the 741 operational amplifier used for the current-to-voltage converter acts as a low-pass filter to smooth the waveform. If you use a higher frequency op amp, a capacitor shunting R3 will serve to low pass filter the waveform. A −3 dB frequency (F) of 1 or 2 kHz will suffice to smooth the waveform. The value of the capacitor is calculated from:

$$C_{\mu F} = \frac{1{,}000{,}000}{6.28\ R3\ F} \qquad \textbf{(3)}$$

Where:

$C_{\mu F}$ is the capacitance in microfarads

F is the −3 dB cut-off frequency in hertz (Hz)

R3 is expressed in ohms

This circuit is synchronized by a clock oscillator consisting of a single 555 IC timer. Although not a TTL device, the 555 is TTL-compatible when the V+ potential applied to pins 4 and 8 is limited to +5 volts DC. The 555 is connected in the astable multivibrator configuration, causing it to output a chain of pulses with a +4 volt amplitude. The operating frequency is set by three resistors (R3, R4, and an external potentiometer) and a capacitor selected by the user. The actual clock frequency is:

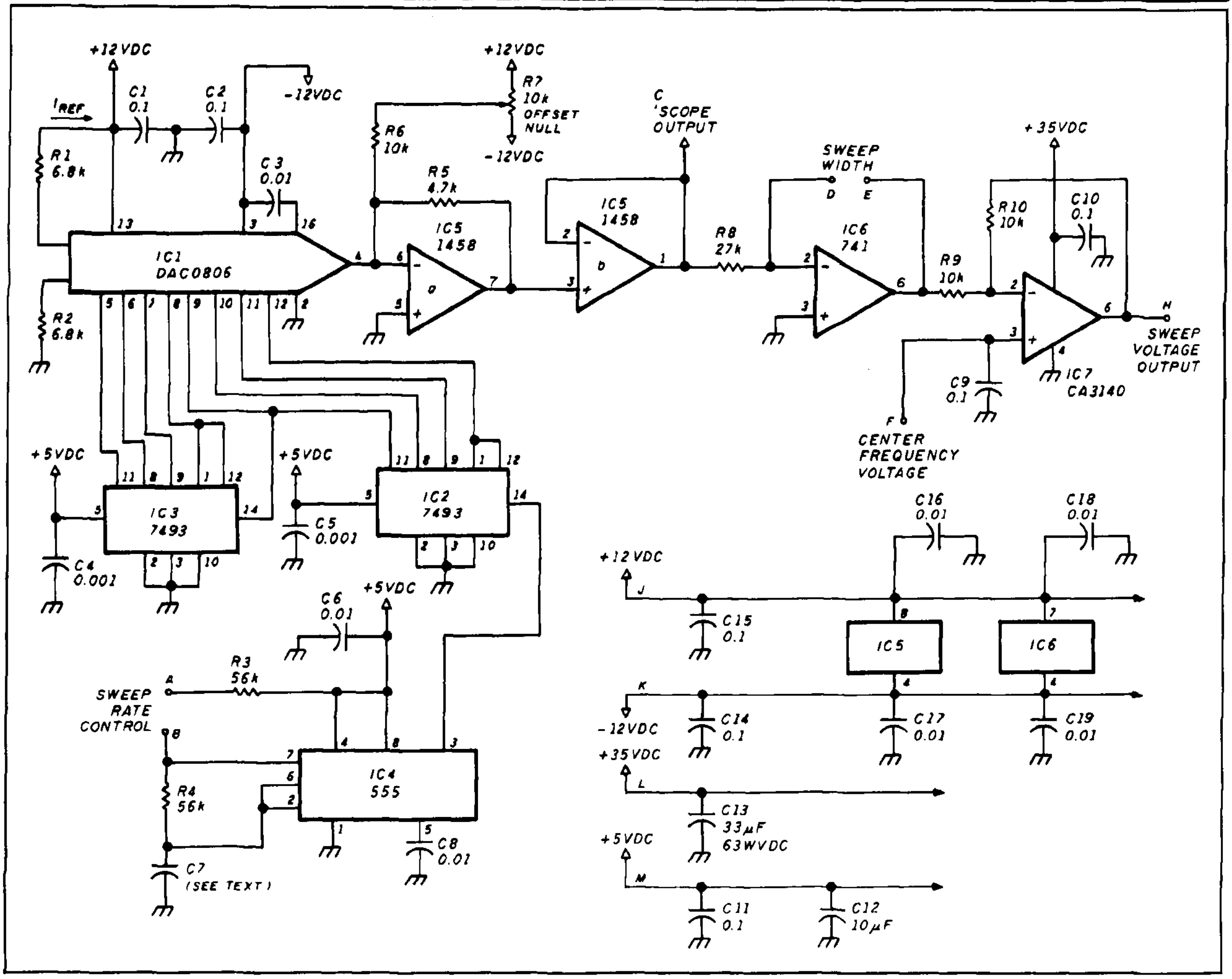
$$F = \frac{1.44}{((R3 + R12) + 2R4)\ C} \qquad \textbf{(4)}$$

Where:

F is the frequency in hertz (Hz)

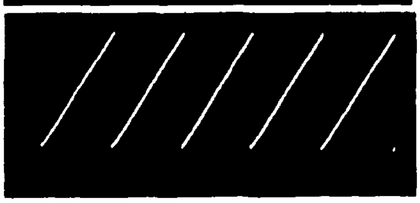
C is in farads

FIGURE 1



Schematic of the circuit for generating the digital sawtooth output.

PHOTO A



The "normal" output of the sawtooth generator.

R3, R4, and R12 are in ohms

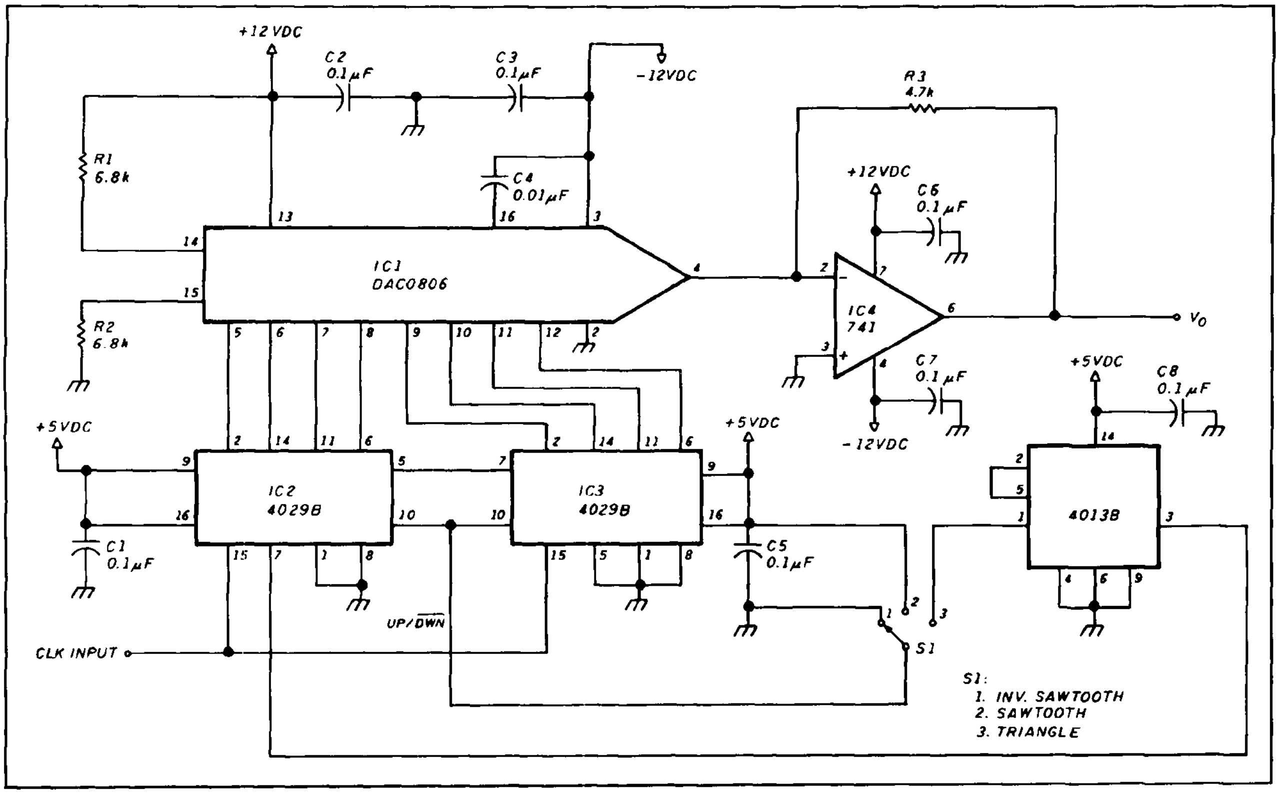
Select a clock frequency that's 256 times the desired sawtooth fundamental frequency. For example, if you want to sweep the spectrum analyzer at 30 Hz, select a clock frequency of 30 × 256, or 7680 Hz.

I selected two outputs for this project. Point "C" is a fixed positive-going output of about 1.5 volts. For purposes of the spectrum analyzer, this output drives the horizontal input of the oscilloscope used with the project. The signal present at this output is shown in **Photo A**.

You'll see a positive-going sawtooth riding on top of a DC level at point "H." The DC control voltage that sets the center frequency of the spectrum analyzer is applied to point "F," which is also the noninverting input of the operational amplifier. Because the noninverting input sees a gain of 2, the voltage applied to point "F" should be one-half the maximum fixed tuning voltage. The op amp used for the output stage is an RCA/GE CA-3140 device chosen because it can tolerate a power supply differential between V+ and V− of 44 volts DC. However, in this circuit the supply voltage for the output stage is limited to about 35 volts DC, which is the maximum tuning voltage required of the spectrum analyzer.

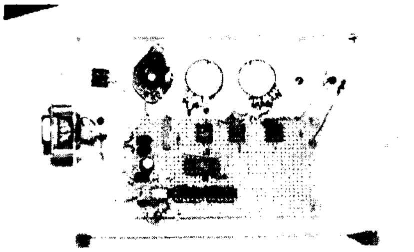
After building a version of the circuit shown in **Figure 1** for use with my spectrum analyzer, I decided that it would be nice to have a sawtooth generator on the workbench. My interest was heightened by the fact that I'm working on an RF sweep generator for the HF Amateur bands and need to do some additional development work. **Photo B** shows the finished project. It has both positive and

FIGURE 2



Partial schematic of the digital sawtooth generator with the modification to allow normal, inverted, and triangle wave outputs.

PHOTO B



The completed circuit in its enclosure.

negative-going outputs, as well as the ability to select internal and external clocks. If you want a copy of the circuit, just send me a no. 10 SASE.

Sawtooth/triangle generator

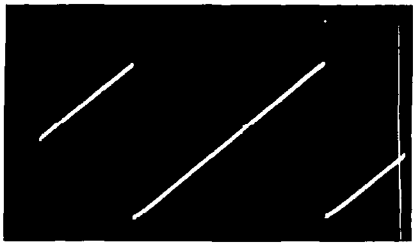
Because of several letters I've received, and the requirements of the "bandsweeper" signal generator that I'm building, I designed and built a new generator circuit. This circuit (shown in **Figure 2**) is made to output one of the following waveforms: **a)** positive-going sawtooth, **b)** negative-going sawtooth, and **c)** triangle wave. Once again, the heart of the circuit is a DAC0806 digital-to- analog converter chip (IC1). This part of the circuit, including the operational amplifier (IC4) current-to-voltage converter stage, is the same as the previous designs. The difference lies in the binary counter stages.

The circuit in **Figure** 1 used a pair of 7493 base-16 counters in cascade to drive the DAC binary inputs. The outputs of these counters increment from 00000000 to 11111111, and return to 00000000 on the next step. Thus, the DAC output is a positive-going sawtooth. However in this circuit, the counters are CMOS 4029B devices. The 4029B is an up/down, binary/decade synchronous counter. Pin 9 is the BIN/DEC control. When pin 9 is **low**, the 4029B is a decade (base-10) counter. But because you need a binary counter, pin 9 is tied **high**. Pin 10 on the 4029B is the **direction** control. When pin 10 is **high**, the 4029B acts as an ordinary up counter and increments "forward" from 00000000 to 11111111, and then goes back to 00000000 on the next count. When pin 10 is **low**, the 4029B becomes a down counter. In this mode it decrements from 11111111 backwards to 00000000, and recycles to 11111111 on the next count. The key to the operation of the circuit in **Figure 2** lies in the control of the direction of counting:

- **Positive-going sawtooth**: Use the 4029B as an up counter (pin 10 **high**).
- **Negative-going sawtooth**: Use the 4029B as a down counter (pin 10 **low**).
- **Triangle waveform**: Use the 4029B both as an up and down counter, controlling direction with external logic.

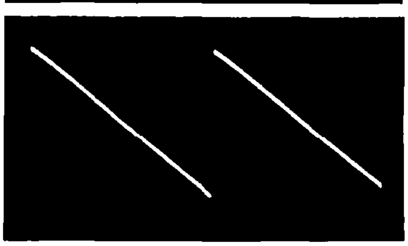
An SP3T switch (S1) does the switching between the output waveforms. The switch's wiper drives the up/down control line. In position 1, the up/down line is connected to ground, producing a negative-going "inverted" sawtooth waveform from the DAC. In position 2, it's connected to +5 volts DC, producing a regular positive-going sawtooth. In position 3, the switch up/down line is connected to the output of the direction control logic — a single CMOS 4013 chip.

PHOTO C



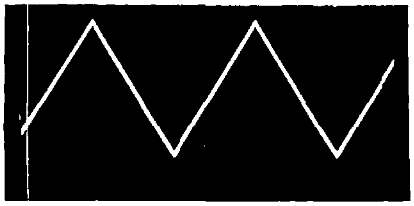
Positive going sawtooth waveform.

PHOTO D



Negative-going (inverted) sawtooth waveform.

PHOTO E



Triangle waveform at a frequency of one-half of the sawtooth output.

The 4013B is a dual type D flip-flop (only one used). The 4013B has two modes, clocked and direct (use the clocked mode). In the clocked mode, the reset (pin 4) and set (pin 6) inputs are grounded to hold them low. The rule of operation for a clocked type D flip-flop is simple. When the clock (pin 3) is high, whatever logic state appears on the D input (pin 5) is transferred to the Q output (pin 1), and its complement appears on Q-NOT (pin 2). Cross-coupling Q-NOT and D provides binary division (the mode needed), so strap pins 2 and 5 together.

The out terminal (pin 7) on the 4029B counter has a very interesting action. The counter goes low momentarily on count 1111, so it's normally used for cascading stages of 4029B devices. It's used in this way to cascade IC3 to IC2. The out terminal of IC2 goes low momentarily when the total eight-bit count is 11111111, so it's used to drive the clock input on the 4013. When the out terminal of the 4029 toggles, it causes the 4013 output to change state. Because the 4013 Q output is used to drive the up/down input on the 4029B devices, this action forces the counter direction to reverse. Thus, in this mode, the 4029B cascaded counters increment 00000000 to 11111111, and then decrement 11111110, 11111101, and so forth, back to 00000000 — where still another reversal takes place.

The output waveforms of the circuit in Figure 2 are shown in Photos C, D, and E. These oscilloscope photos were taken with a clock frequency of approximately 100 kHz, and represent sawtooth frequencies of just under 400 Hz. The positive-going sawtooth is shown in Photo C, while the negative-going version is shown in Photo D. The sawtooth output is shown in Photo E. This waveform has a frequency of one-half the sawtooth frequency, taken with exactly the same clock frequency. Note that the photos were not taken with the same oscilloscope timebase setting. Thus, the sawtooth waveform is $F_{clk}/256$, while the triangle waveform is $F_{clk}/512$.

Conclusion

Digitally generated sawtooth and triangle waveforms are simple and easy. I suppose the next trick is to generate square waves, variable width pulses, and sine waves without using read-only memory chips. Anyone have any ideas? If so, my QTH address is below.

I can be reached at POB 1099, Falls Church, Virginia 22041; I'd like to have your comments and suggestions for this column. hr

VHF/UHF ANTENNA TUNERS

An easy, inexpensive project

By Bill Schreiber, NH6N, 73-4327 Imo Street, Kailua-Kona, Hawaii 96740

Some time ago, I succumbed to the lure of satellite operation and proceeded to acquire equipment. I selected the Yaesu FT-726R as my base station and cobbled up antenna rotators out of cheap, readily available components. I found the Cushcraft Oscar pair 416-TB and A144-20T to my liking (the price was right), and mounted them on my homebrew rotator combo. I also bought the Kenwood SW-200 SWR and Power Meter, plus its three sensors.

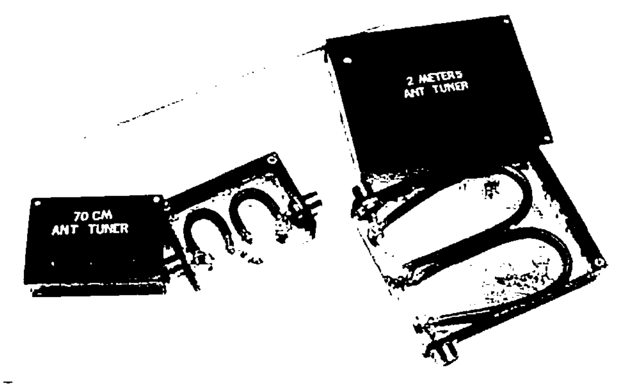
I set up the antenna system, but was unhappy with its bandwidth performance. It occured to me that a VHF/UHF antenna tuner would be a worthwhile addition to the overall system. When I was unable to locate any that I liked in my magazines, I resigned myself to spotty satellite operations. But I continued to research the literature for suitable devices.

I finally found my answer in a *Ham Radio* article by Joe Reisert, W1JR, called "Impedance Matching Techniques."[1] I have been a fan of Joe's for years and always look forward to his coverage of the spectrum above the humdrum HF bands.

Pages 33 and 34 of his article contain a description and outline of tunable antenna matchers suitable for my 2-meter and 70-cm Cushcrafts. They were easy and inexpensive to build, which was a key consideration for me. My out-of-pocket expenses for the trimmer capacitors for each unit were less than $2. The rest of the parts came out of my junkbox.

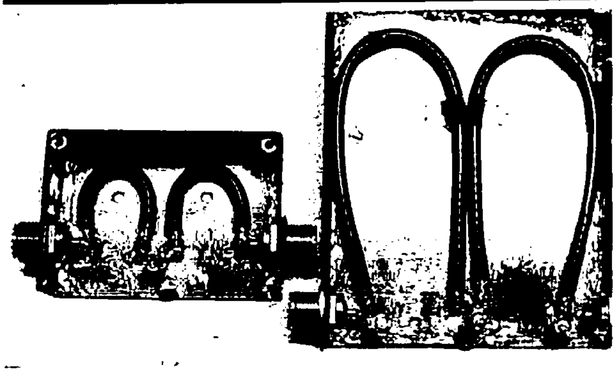
Photo A shows the two units. Dimensions of the RG-8X coaxial cable elements and boxes are indicated in Table 1. They are based on Reisert's suggested 3/16 wavelength multiplied by the 0.65 velocity factor of the coax. I used this cable because it was on hand. RG-58 would work as well. In fact, you can use RG-8 if you can bend it into shape and clamp it in position. More details are shown in Photo B (side-by-side views of the two units). Figure 1 is the schematic of the matchers from W1JR's article.

PHOTO A



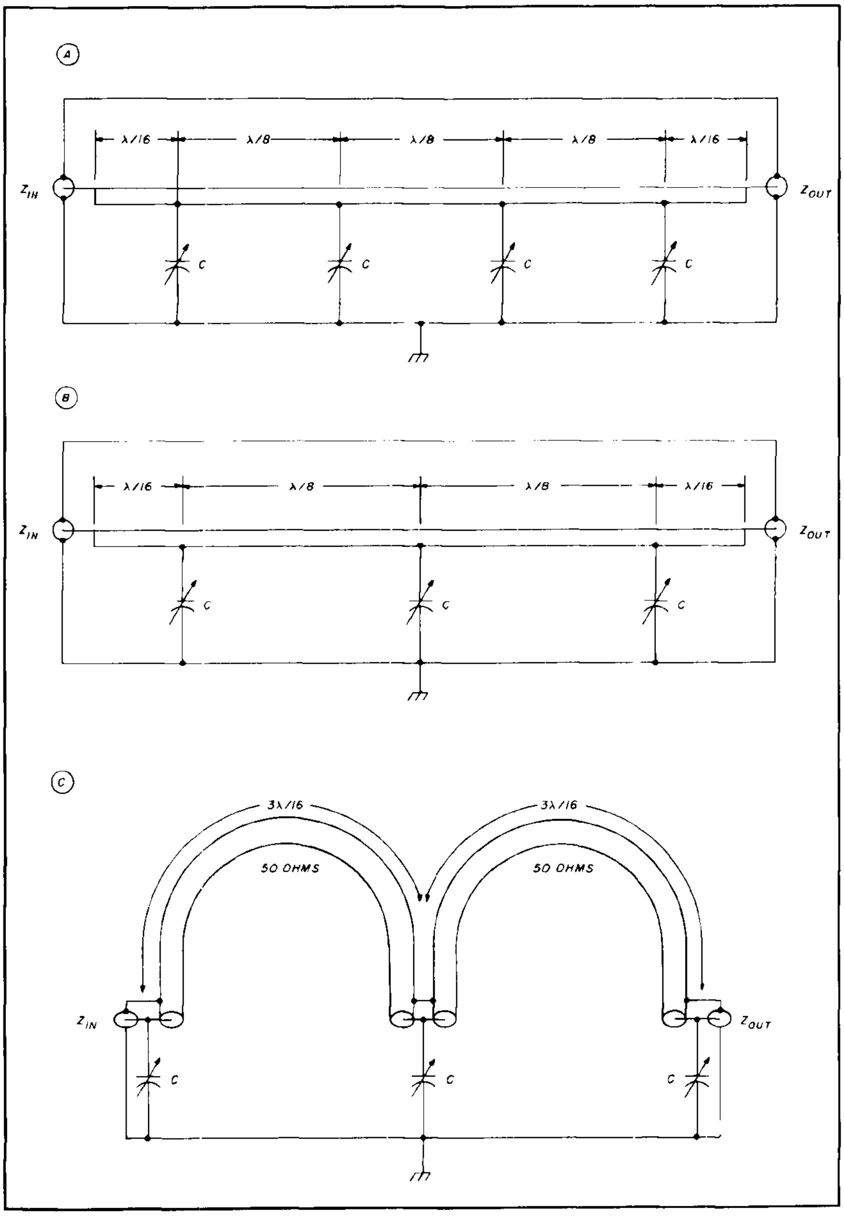
70-cm and 2-meter antenna matching units with covers removed.

PHOTO B



Close-up view of the 70-cm and 2-meter matching units. Trimmer capacitors are visible at the bottom of the coax loops.

FIGURE 1



Examples of coaxial-type antenna tuners: (A) half-wavelength adjustable transformer; (B) three-eighths wavelength adjustable transformer; (C) three-eighths wavelength adjustable transformer using coaxial cable.

TABLE 1

	Dimensions 2 meters	70 cm
Box	5.75″ x 4.5″ x 1″	3.5″ x 2.5″ x 1″
Coax	15.275″	5.165″
Trimmers	6 to 60 pF	2 to 20 pF

Before mounting the coax, prepare each end by stripping off 0.5" of the insulation and 0.25" of the shield. Take 1" of no. 20 bare wire, wrap part of it around the exposed shield, and solder it carefully in place. Too much heat here will melt the insulation. This should leave about 0.5" of free end for attaching the assembly to the chassis. Solder a 0.5" piece of the same type wire to the center conductor. Perform this cable preparation at each end of the four pieces of coax you've cut to length.

Your next step is to construct the combination chassis/box for the tuners. I gave up on the prefabricated metal boxes offered for construction projects years ago, in favor of using double-sided circuit board. These boards are widely available from electronics catalogs, as well as "surplus" electronics stores. They're inexpensive, tough, and easy to work. They also let you make enclosures which fit your exact requirements. I cut the circuit board with a carbide saw blade in my scroll saw. A word of caution here: the fiber glass core of the circuit board is murder on conventional steel saw blades, but the carbide ones seem to last forever. Once they are cut to size, it's a simple matter to solder the overlapping sections together. I also soldered 6/32 brass nuts in the corners so I could use a removable lid.

Cut the large holes for the SO 239 sockets prior to assembly. Be sure to keep the coax off the chassis at a height equal to the SO 239 center pin. In my first configuration, the coax was almost flush with the chassis and arcing occurred whenever the power level got over about 5 watts.* You must mount the trimmers with due regard for short leads and stiffness, since you will be pushing against them when they are being tuned. They should also be positioned directly under the holes cut in the lid to permit accurate insertion of the tuning tool.

Connect the tuners to the antenna on one side and the SWR/Power Meter on the other. Hook the rig into the SWR/Power Meter on the opposite side. Set the rig in its tune or CW position, reduce the drive to a very low level, and fire it up. I started with the trimmers in their minimum capacity position, and proceeded to adjust them progressively from the antenna side for minimum SWR. Once the SWR is at a tolerable level, increase the drive to max slowly, tweaking the trimmers as necessary. Don't panic if you seem to run out of adjustment room with the trimmers in either maximum or minimum position. Bend the coax gently up or down towards the chassis and you'll find a spot where the trimmers have sufficient range to permit a deep null in the SWR as read off the meter. Balancing all of the adjustments is particularly sensitive on 70 cm. Keep the relative fragility of the trimmers in mind, and don't use too much muscle.

I found that my setup stays at about 1.2:1 from 144 to 148 MHz on 2 meters. I acheived comparable results in the 435-MHz band. **hr**

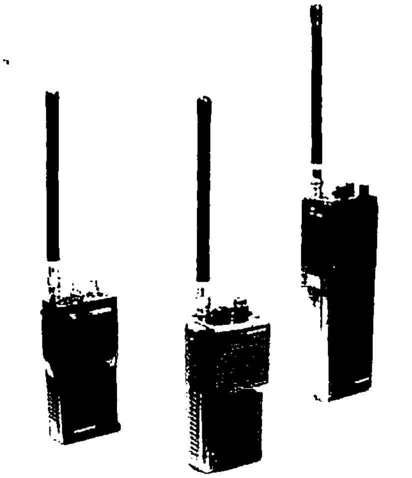
REFERENCE

1. Joe Reisert, W1JR, "VHF/UHF World Impedance Matching Techniques," *Ham Radio*, October 1987, page 27.

*For power levels greater than = 10 watts, I recommend using the following trimmers from Fair Radio Sales Co., P.O. Box 1105, 1016 E. Eureka St., Lima, Ohio 45802: 3D9025V-99 (3.2 - 25 pF) and 3D9100V (10 - 100 pF).

Nady EasyTalk™ Two-Way Radios

Nady Systems' line of VHF portable radios brings high-quality transceivers to all two-way radio users. The full-featured portables all list for under $300.



The VHF-40 is a 5-watt/six-channel transceiver with a 5 to 7-mile range, priced at $249. It uses a diode matrix to synthesize the signal from one crystal, and then programs it to function on up to six different frequencies. It can be programmed using the silicon diodes and the instructions included. The transceiver is powered by a battery pack that uses either rechargeable NiCd or standard AA batteries.

The VHF-30 is a miniature 5-watt/four-channel radio that transmits at a 5 to 7-mile range. It sells for $299. The unit weighs just 15 ounces and has a rugged, impact-resistant case which resists weather and contaminants.

Nady's VHF-20 is a 2-watt/two-channel model listing for $249. The pocket-sized unit has a high/low switch that changes the signal from 2 to 0.5 watts, conserving the battery pack when maximum range isn't needed.

Nady VHF radios come with a "rubber duck" antenna with a BNC connector, an AC/DC wall charger, a stainless steel belt clip, a holster-style carrying case, and a NiCd rechargeable battery pack. Nady also offers customizing options for the transceivers, including a Continuous Tone Coded Squelch System (CTCSS), a remote microphone/speaker, a high-speed desk charger, and a heavyweight leather carrying case.

For more information contact Nady Systems, Inc., 1145 65th Street, Oakland, California 94608. Phone (415)652-2411.

Circle #307 on Reader Service Card.

New catalog from Contact East

A complete source book of products for testing, repairing, and assembling electronic equipment is now available from Contact East at no charge. The new, 132-page *1989 General Catalog* contains products for engineers, managers and technicians. All products are guaranteed. Contact East's "same-day shipment" policy assures fast delivery; orders received by 3 p.m. are shipped by 5 p.m. For your free copy and one year of technical supplements, write to Contact East, PO Box 786, 335 Willow Street, North Andover, Massachusetts 01845.

Circle #308 on Reader Service Card.

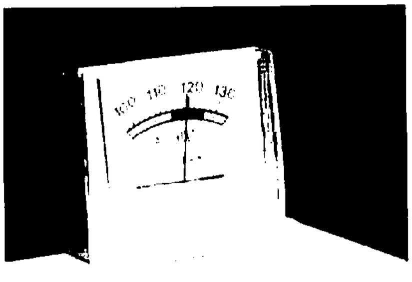
MFJ-850 AC Line Voltage Monitor

The new MFJ-850 provides protection from low-voltage "brown-out" conditions that can damage your electrical equipment. Just plug it in, it tells you at a glance when your line voltage is at a low brown-out level. The expanded scale reads from 95 to 135 volts; color coding makes across-the-room reading easy. Leave it plugged in permanently for constant monitoring. It comes with MFJ's one-year unconditional guarantee.

The monitor's compact size (2-1/4 × 2-1/4 × 1-1/2 inches) allows for at-home or mobile use. Use it to check computer/peripheral or video setups, portable generators, and temporary electrical setups.

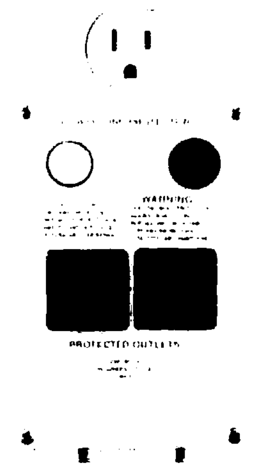
For more information contact MFJ Enterprises, Inc., PO Box 494, Mississippi State, Mississippi 39762. Phone (601)323-5869. To order call toll free at (800)647-1800.

Circle #309 on Reader Service Card.



New Surge Protection from Kalglo

Kalglo Electronics Company, Inc. announces the new TeleSpiker™ series surge suppressors/power line filters with integral protection for RJ45/RJ11 modular telephone jacks. They are specially engineered to meet the protection needs of FAX machines, modems, electronic telephones, and other devices using modular jacks.



The "Mini-T" is a compact, two-outlet plug-in system complete with modular extension cord. Using Kalglo's Premium Protection™ circuitry, the Mini-T has full series/parallel load-bearing filtering for maximum EMI/RFI protection. The Mini-T is rated at 140 volts clamping, with a total of 436 joules energy absorption. The suggested list price is $85.95.

For more information contact Kalglo Electronics Company, Inc., Dept Mini-T, 6584 Ruch Road, East Allen Township, Bethlehem, Pennsylvania 18017-9359. Phone (215)837-0700.

Circle #310 on Reader Service Card.

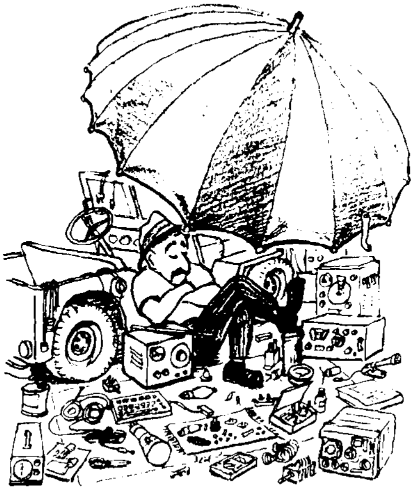
ICOM's new wideband SSB filter for the IC-781

ICOM announces the FL-103 wideband SSB filter for the IC-781 HF transceiver. The 2.8-kHz SSB filter fits in the 9-MHz IF of the IC-781 and provides improved SSB audio fidelity.

The FL-103 is currently available for $72.50.

Contact ICOM America Inc., 2380 116th Avenue N.E., PO Box C-90029, Bellevue, Washington 98009-9029.

Circle #311 on Reader Service Card.



FLEA MARKET

RATES Noncommercial ads 10¢ per word; commercial ads 60¢ per word **both payable in advance**. No cash discounts or agency commissions allowed.

HAMFESTS Sponsored by non-profit organizations receive one free Flea Market ad (subject to our editing) on a space available basis only. Repeat insertions of hamfest ads pay the non-commercial rate.

COPY No special layout or arrangements available. Material should be typewritten or clearly printed (**not** all capitals) and must include full name and address. We reserve the right to reject unsuitable copy. **Ham Radio** cannot check each advertiser and thus cannot be held responsible for claims made. Liability for correctness of material limited to corrected ad in next available issue.

DEADLINE 15th of second preceding month.

SEND MATERIAL TO: Flea Market, Ham Radio, Greenville, N. H. 03048.

BEGINNER'S RADIO CLEARINGHOUSE. On a space available basis, we are going to offer you, OUR SUBSCRIBER, free of charge, a chance to find a home for your used equipment with a new Ham. Please send us a short description of what you want to sell along with price, name, address and phone number. We'll run it once in a special section of the classified ads under the heading of BEGINNER'S RADIO CLEARINGHOUSE. Please limit your ad to 20 words or less.

NATIONAL Radio Manual and NCL-2000 factory parts lists. SASE. Max Fuchs, 11 Plymouth Lane, Swampscott, MA 01907.

CUSTOM MADE EMBROIDERED PATCHES. Any size, shape, colors. Five patch minimum. Free sample, prices and ordering information. HEIN SPECIALTIES, Inc., 7960 SW Manitou Trail, Glen Arbor, MI 49636. (616) 334-4385.

100 QSL CARDS $8. $3 thereafter. Grid square printed free. Shipped postpaid within two weeks. Guaranteed correct! Free samples. Shell Printing, KD9KW, Box 50B, Rockton, IL 61072.

LET THE GOVERNMENT FINANCE your small business. Grants/loans to $500,000 yearly. Free recorded message: 707-448-0270. (KH5)

NEED SCHEMATIC of Hallicrafter SX110 receiver. Will pay reasonable price. A.T. Butler, 1157 Rivermont Drive, Melbourne, FL 32935.

INTERESTED IN QRP? $1 brings 8-page information brochure plus sample of The QRP Quarterly. Joe Sullivan, WA1WLU, 267 Sutton St, North Andover, MA 01845.

HAM RADIO. Complete run Volume 1, No. 1 (March 1968) through May 1982. Very good condition. $95. W1JE, 6 Locust Grove Road, Harwich, MA 02645.

RADIO SHACK COLOR COMPUTER. Ham software and hardware. Free catalog. Dynamic Electronics, Box 896, Hartselle, AL 35640. (205) 773-2758.

COMMUNICATIONS BATTERIES: HT-Clone-Packs! ICOM: BP-3S double BP3 "Wall Chargeable" $43.95, BP5 $42.95, YAESU: FNB2 $21.95, SANTEC 142/442/1200 (3 pin) $22.95. "Rebuilding—Send-Ur-Pack" ICOM BP3 $20, BP5 $28, BP7/8 $34, YAESU FNB4/4A $38, Kenwood PB21 $18, PB 25/H/26 $28, T-T 2991 $29. "U-Duit Repair Inserts". ICOM PB2 $18.95, BP3 $16.95, BP5 $23.95, BP7/BP8 $28.95, Kenwood: PB21 $12.95, PB24 $19.95, Azden 300 $22.95, YAESU: FNB4/4A $32.95, TEMPO: S1,2,4,5,15/450 $22.95, "Antennas" 2Mtr 5/8-Tel/BNC $18.95. "Cordless Phone & Pager Batteries" Best Price—Free Catalog $3 shipping/order. PA + 6%, VISA-MC + $2 (814) 623-7000. CUNARD ASSOCIATES, Dept H, RD 6, Box 104, Bedford, PA 15522.

R-390A Receiver Parts: Info SASE. CPRC-26 military Manpack Radio, 6 meter FM, with antenna, crystal, handset: $22.50, $42.50/pair, radio-only $9.50. Military-spec TS-352 Voltohm/Mullimeter, leads, intor: $12.50. Patrol Seismic Intrusion Device ("PSID") TRC-3 $37.50 apiece, $127.50/set of four. Add $4.50/piece shipping, $9 maximu. Bayutronics, Box 591, Sandusky, OH 44870.

HAM PROGRAMS and other "shareware" for IBM/compatibles. Large SASE for catalog. JK&S, POB 50521, Indianapolis, IN 46250-0521.

REPEATER JAMMERS? Pinpoint them with our "Handi-Finder" — attaches to HT. Kits: $24.95, or less! Club project discounts! NOARO, 29460-H Lorain, Cleveland, OH 44070. (216) 777-9460.

ICOM, KENWOOD & YAESU OWNERS: 8 pole and 10 pole crystal filters and monthly informative individual newsletters! Our 10th year. Ask yourself these questions. Are you continually being interfered with during QSO? You can't seem to pull out a weak signal in the QRM? Yes, to either, purchase our SSB or CW filters. Send .45 SASE for free catalog. International Radio & Computers, Inc, 751 SW Macedo Blvd, Port St. Lucie, FL 34983. (407) 879-6868.

HAM SOFTWARE IBM/Compatibles. 10 disks $26.95. MC/VISA/Discover. N5ABV EAPCO, Keller, TX 76248-0014. (817) 498-4242.

WANTED: Old tube HiFi and studio components, loudspeakers, turntables, related magazines etc. Most makes and models, any condition. Jack Smith, 288 Winter Street, North Andover, MA 01845.(508) 686-7250.

UHF TEST EQUIPMENT: Hewlett-Packard TS403 (616B). UHF Signal Generator 1.8-4 GHZ $50. Jerrold VHF-UHF sweep generators $50.00. Tektronix 661 dual trace scopes (DC-3900 MHz!) no leads. $50. Avionics glide path and localizer sig. gen. $75 checked; $40 unchecked. AUL 1-7 GHZ sig. gen. $50. WW5B, POB 460, Brookshire, TX 77423.

POLICE/FIREFIGHTER HAMS - Please send your Call, Name, Address, Rank, Department Name, for inclusion in special roster available late 1989. Capt. Bob Blakeslee, N2IHQ, 1-1/2 Macomber Ave, Binghamton, NY 13901.

WANTED: Ham equipment and other property. The Radio Club of Junior High School 22 NYC, Inc. is a nonprofit organization, granted 501(C) (3) status by the IRS, incorporated with the goal of using the theme of Ham Radio to further and enhance the education of young people nationwide. Your property donation or financial support would be greatly appreciated and acknowledged with a receipt for your tax deductible contribution. Have a wonderful vacation but remember your support is needed as much in the summer as the rest of the year. WB2JKJ and the crew do not stop when school does. Please write us at: PO Box 1052, New York, NY 10002. Round the clock hotline: (516) 674-4072. Thank you!

ELECTRONIC KITS & ASSEMBLIES. For our latest catalog send a large SASE (45 cents) to: A & A ENGINEERING, 2521 W. LaPalma, #K, Anaheim, CA 92801.

IBM-PC SOFTWARE FOR PK-232. New CompRtty II/PK is the complete communications program for the PK-232/HK-232. Uses host mode of PK-232 for complete control. Text entry via built-in screen editor! Adjustable split screen display, including optional Triple Split ™ in Packet mode. Instant mode/speed change. Hardcopy, diskcopy, break-in buffer, select calling, text file transfer, customizable full screen logging, 24 programmable 1000 character messages, mailbox facility. Ideal for MARS and traffic handling. Requires 256k PC compatible. $65. Non-PK-232 version still available. Send call letters (including MARS) with order. David A. Rice, KC2HO, 144 N. Putt Corners Rd, New Paltz, NY 12561.

COMMODORE REPAIRS. One of the Oldest/largest Commodore repair centers in the country. C-64 $34.95 plus UPS, C-128 $69.95 plus UPS (ends 8/30/89). Same day shipment. Ask about the "Diagnostician" trouble-shooting guide. 10 years in business with reliability and customer satisfaction. Commodore/Amiga Chips complete stock, massive inventory. Power Supplies, disk drives, etc. Call us last for the best prices in town. Dealers write us on your letterhead for confidential price sheet. Kasara Microsystems, Div.of QEP, Stony Point, NY 10980. 1-800-248-2983 or 914-942-2252.

R-290A Receiver Parts: Info SASE. CPRC-26 military Manpack Radio, 6 meter FM, with antenna, crystal, handset: $22.50, $42.50/pair. CPRC-26 Radio-only: $9.50. Add $4.50/piece shipping, $9 maximum. Baytronics, Box 591, Sandusky, OH 44870.

FOR SALE: Browning Golden Eagle Mark IV AM/SSB citizen's band receiver. Superb performance—tube-type double conversion, low noise, two tunable bands or crystal controlled. Use on CB, retune for 10 meters, or use as tunable IF for 2 meter, satellite or microwave receiver. Missing top cover, otherwise complete and working, with schematic. $100.00. Peter Ferrand, WB2QLL, 65 Atherton Avenue, Nashua, NH 03060. (603) 889-1067.

KENWOOD OWNERS: Increase the bandspread of your TS-940, TS-930, TS-440 or TS-430! Our Tuning Upgrader adds a new, slower 2.5 kHz/revolution (1/4 speed) fine-tuning rate and automatically selects higher-speed tuning rates when you tune faster, for quick QSY. Easy to install. $34.95. TS-940 Owners: Bank Controllers I & II allow front panel memory bank control, (using voice button) eliminating need to go to top to slide open hatch each time to change memory bank. #II also permits voice frequency announcement. #I—$24.95. #II—$49.95. $5.00 S/H USA. $13.00 elsewhere. International Radio & Computers, Inc, 751 SW Macedo Blvd, Port St. Lucie, FL 34983. Send .45 SASE for catalog. (407) 879-6868.

WANTED: All types of Electron Tubes. Call toll free 1-800-421-9397 or 1-612-429-9397. C & N Electronics, Harold Bramstedt, 6104 Egg Lake Road, Hugo, MN 55038.

SCHEMATICS. Devices, modules and components. Catalog $1.00 refundable. Free flyer LSASE. George Whitmore, 5746 Aberdeen Angus Way, Las Cruces, NM 88001.

UHF PARTS. GaAs Fets, mmics, chip caps, feedthrus, teflon pcb, high Q trimmers. Moonbounce quality preamps. Electronic sequencer boards. Send SASE for complete list or call (313) 753-4581 evenings. MICROWAVE COMPONENTS, PO Box 1697, Taylor, MI 48180.

COMMODORE-128 PROGRAM available to track the Amateur Satellites. Uses Keperlian data supplied by NASA free. Tracks up to 8 satellites simultaneously. Program also supports printing schedules and predictions for satellites. Use it to track MIR and talk to the Cosmonauts. SATRAK128, $26.50 includes shipping. Other information on this or other programs for the C128, requires a business size SASE. Reid Bristor, WA4UPD, PO Box 0773, Melbourne, Florida 32936-0773.

WANT: 32S3 xmtr, 250TL and 304TL tubes. KF6WM, 45300 Royal, King City, CA 93930.

HANDICAPPED NOVICE needs HF equipment donated—anything please. KA3OUE, (412) 531-7443 anytime.

OFFICIAL MILITARY-TYPE ID TAGS. ("Dog Tags")!! Customized with your Call Letters, etc. 5 seventeen space lines. 20" nickel plated chain included. $4.29 postpaid. JPW ENTERPRISES, PO Box 353, Logan, Utah 84321.

MAGAZINES WANTED: "Microwave Systems News" (MSN), "RF Design", "PCIM (Power Conversion & Intelligent Motion)" and "QEX" (1980-present). Call collect 519-742-4594 (Ontario) after 6 PM Eastern time.

IMRA International Mission Radio Association helps missionaries. Equipment loaned. Weekday net, 14.280 MHz, 1-3 PM Eastern. Nine hundred Amateurs in 40 countries. Rev. Thomas Sable, S.J., University of Scranton, Scranton, PA 18510.

"SOME UNPUBLISHED THEORIES and MORE for The Radio Amateur" by Lymansson. Includes RF wattmeter, moni-match, balun etc. From R.L. Pfohl-Beeman, Publisher. $10 ppd. POB 70, Loogootee, IN 47553.

CHATHAM, CAPE COD vacation ham shack on top of windmill overlooking Nantucket Sound and Inlet. 2 fireplaces, cable, modern kitchen, jacuzzi tub, 4 bedrooms. Walk to beach. Great shops and restaurants. Kenwood **TS-440S**. Great DX. Rent off season only. For pictures and brochure SASE to Edwards/N2HGP, 24 Edgewood Road, Scarsdale, NY 10583.

BACK ISSUES OF HAM RADIO. Have most issues from 1969 to 1974. Mint condition. $3.00 for single issues. WN0G, 319-377-3563.

HAM TRADER YELLOW SHEETS. In our 27th year. Buy, swap, sell ham radio gear. Published twice a month. Ads quickly circulate—no long wait for results. Send No. 10 SASE for sample copy. $13 for one year (24 issues). PO Box 2057, Glen Ellyn, IL 60138-2057 or PO Box 15142, Dept HR, Seattle, WA 98115.

VHF-UHF-SHF. Large SASE. West Coast VHFer, POB 685, Holbrook, AZ 86025.

CHASSIS & CABINET KITS. SASE. K3IWK, 5120 Harmony Grove Rd, Dover, PA 17315.

ANALOG AND RF CONSULTING for the San Francisco Bay area. Commercial and military circuits and systems. James Long, Ph.D., N6YB (408) 733-8329.

RTTY JOURNAL—Now in our 36th year. Read about **RTTY**, AMTOR, PACKET, MSO'S, RTTY CONTESTING, RTTY DX and much more. Year's subscription to RTTY JOURNAL $10.00, foreign slightly higher. Order from: RTTY JOURNAL, 9085 La Casita Ave., Fountain Valley, CA 92708.

RUBBER STAMPS: 3 lines $5.00 PPD. Send check or MO to G.L. Pierce, 5521 Birkdale Way, San Diego, CA 92117. SASE brings information.

ELECTRON TUBES: Receiving, transmitting, microwave... all types available. Large stock. Next day delivery, most cases. DAILY ELECTRONICS, PO Box 5029, Compton, CA 90224. (213) 774-1255.

"HAMLOG" COMPUTER PROGRAM. Full features, 17 modules. Auto-logs, 7-band WAS/DXCC. Apple $19.95. IBM, CP/M, KAYPRO, Tandy, C128 $24.95. HR-KA1AWH, POB 2015, Peabody, MA 01960.

WANTED: ARC-5 and SCR-274 equipment, parts and accessories, any condition. Ken, WB9OZR, 362 Echo Valley, Kinnelon, NJ 07405. (201) 492-9319.

WANTED: Ham equipment and other property. The Radio Club of Junior High School 22 NYC, Inc. is a nonprofit organization, granted 501(C) (3) status by the IRS, incorporated with the goal of using the theme of Ham Radio to further and enhance the education of young people. Your property donation or financial support would be greatly appreciated and acknowledged with a receipt for your tax deductible contribution. In Dayton, meet the crew from 22 and relax at our flea market tables, check in on 144.30 simplex. Please write us at: PO Box 1052, New York, NY 10002. Or call our round the clock hotline: (516) 674-4072. Thank you!

WANTED: Drake Linear Amp Model MN4439- 1000W (2000 PEP), 1.8-30 MHz. Call Bruno Molino, VE2FLB, 26 Rue Des Anciens, Gatineau, Quebec J8T 3T2 (819) 561-3689

RECONDITIONED TEST EQUIPMENT $1.25 for catalog. Walter, 2697 Nickel, San Pablo, CA 94806.

COMING EVENTS

Activities — "Places to go . . ."

SPECIAL REQUEST TO ALL AMATEUR RADIO PUBLICITY COORDINATORS: PLEASE INDICATE IN YOUR ANNOUNCEMENTS WHETHER OR NOT YOUR HAMFEST LOCATION, CLASSES, EXAMS, MEETINGS, FLEA MARKETS, ETC. ARE WHEELCHAIR ACCESSIBLE. THIS INFORMATION WOULD BE GREATLY APPRECIATED BY OUR BROTHER/SISTER HAMS WITH LIMITED PHYSICAL ABILITY.

July 1: COLORADO: Hamfest sponsored by the Western Colorado ARC, Colorado National Guard Armory, Grand Junction. 8 AM to 3 PM. For information contact Randy Martens, NTON, PO Box 3422, Grand Junction, CO 81502. (303) 242-4205.

July 8-9: BRITISH COLUMBIA: Maple Ridge Hamfest sponsored by the Maple Ridge ARC, St. Patricks Center, 22589 121 Avenue, Maple Ridge. For information Bob Houghton, VE7BZH, Box 292, Maple Ridge, BC V2X 7G2.

July 9: ILLINOIS: The DuPage ARC's 17th annual Hamfest/Computer Show, American Legion Post 80, 4000 Saratoga, Downers Grove. Gates open 8 AM. For tickets or reserved tables SASE to Hamfest, W9DOP, PO Box 71, Clarendon Hills, IL 60514 or call (312) 985-0527 evenings or weekends.

July 9: NEW YORK: The 9th annual Batavia Hamfest sponsored by the Genesee Radio Amateurs, Alexander Firemen's Grounds, Rt 98, Alexander. 6 AM to 4 PM. For information contact G.R.A.M., PO Box 572, Batavia, NY 14021.

July 9: NEW YORK: LIMARC ARRL Long Island Hamfair, New York Institute of Technology, Rt 25A, Northern Blvd, Old Westbury. Starts 9 AM. For information Mark Nadel, NK2T (516) 796-2366 or Hank Wener, WB2ALW (201) 694-1811

July 10: ILLINOIS: The DuPage ARC's 7th annual Hamfest Computer Show, American Legion Post grounds, 4000 Saratoga Avenue, Downers Grove. Handi facilities. Tickets $2/advance; $3/gate. For tickets or table reservations SASE to Hamfest Chairman, DuPage RAC, PO Box 71, Clarendon Hills, IL 60514

July 15: NORTH CAROLINA: 17th annual Mid-Summer Swapfest sponsored by the Cary ARC, VFW Building, Reedy Creek Rd, Cary. 9 AM to 3 PM. For information Cary ARC, PO Box 53, Cary, NC 27512

July 15: MAINE: Union Hamfest, Union Fairgrounds, Union. Starts 8 AM. Sponsored by the Maine Hamfest Association, c/o KA1RFB, PO Box 84, East Vassalboro, ME 04935.

July 16: NEW JERSEY: SCARC '89 sponsored by the Sussex County ARC, Sussex County Fairgrounds, Plains Road, off Rt 206, Augusta. Doors open 8 AM. For information write Don Stickle, K2OX, Weldon Road, RD 4, Lake Hopatcong, NJ 07849 (201) 663-0677

July 22-23: COLORADO: Mountain Amateur Radio Club is sponsoring a Hamfest, Red Rocks Campground in Pike National Forest, Woodland Park. Free admission. For camping information/reservations write MARC, Box 1012, Woodland Park, CO 80866 or phone Joe Tafoya, N0CMD (719) 687-3641.

July 23: ILLINOIS: The Amateur Cross Link Repeater's annual Hamfest, "The Hall", 1535 S. Harlem Avenue, Berwyn. 8AM to 1 PM. For information SASE to ACLR, PO Box 348257, Chicago, IL 60634 or call (312) 712-5100

July 28-30. ILLINOIS: The Central States VHF Society's 23rd conference in Rolling Meadows. For information: Chuck Clark, AF8Z, 4N560 Powis Road, W. Chicago, IL 60185

July 28-30: OKLAHOMA: Ham Holiday sponsored by the Central Oklahoma Radio Amateurs, Lincoln Plaza Hotel Conference Center, 4445 Lincoln Blvd, Oklahoma City. For information contact CORA, PO Box 850625, Yukon, OK 73085.
July 30: ILLINOIS: 55th annual Hamfest, sponsored by the Hamfesters Radio Club, Will County Fairgrounds, Peotone. 6 AM to 3 PM. Admission $3/advance; $4/door. For tickets SASE with payment to Hamfesters RC, Donald Burch, N9DWI, 8438 S. Kolin Ave, Chicago, IL 60652 (312) 582-9776.

August 5-6: FLORIDA: The 16th annual Greater Jacksonville Amateur Radio and Computer Show, Prime Osborn Convention Center, 9 AM to 5 PM Saturday and 9 AM to 3 PM Sunday. For information Greter Jacksonville Hamfest Association, PO Box 10623, Jacksonville, FL 32207. Phone (904) 350-9193.

August 6: VIRGINIA: The 39th annual Winchester Hamfest sponsored by the Shenandoah Valley ARC, Clarke County Ruritan Fairgrounds, Rt 7, 2 miles west of Berryville. 7 AM to 3 PM. For information contact Joanne Blaker, WB2CMV at (703) 869-4878 or write SVARC, PO Box 139, Winchester, VA 22601.

October 1: NORTH CAROLINA: JARSFEST '89, Benson American Legion Complex, 301 N. Benson NC 27504. 8 AM to 4 PM. For flyer SASE to Johnston Amateur Radio Society, PO Box 1154, Smithfield, NC 27577. (919) 934-0486, 894-5479.

OPERATING EVENTS

"Things to do . . ."

July 7-6: Special event station VE4IHF will operate from the International Hamfest, International Peace Garden on the border of North Dakota and Manitoba. For QSL card send 1 IRC and SASE to VE4XN, Dave Snydal, 25 Queens Crescent, Brandon, Manitoba Canada R7B 1G1.

July 8: Hobbs, New Mexico. KD5RZ will operate the 1st annual National Royal Ranger Special Event (NRRSE), 1300 to 0100 UTC. Sponsored by the New Mexico Dist. Royal Rangers, a Christian Scouting Organization. For certificate send QSL and large SASE to KD5RZ, 1420 N. Tasker, Hobbs, NM 86240.

July 15: Governor John McKernan has signed a proclamation designating July 15 Amateur Radio Day in the State of Maine. Special event station W1TLC will operate from the Union Hamfest to commemorate Amateur Radio Day.

July 15-23: Fort Amherst Historic Park on P.E.I. The Boy Scouts of Canada are holding Jamboree '89 and will operate fomr the Jamboree site all modes/bands including packet and satellite. Listen for CJ1PEI 24 hours a day, conditions permitting. QSL via Bureau upon receipt of QSL card.

July 16: Fishers Island Sound, NY. Tri-City ARC will operate from Flat Hammock Island, its sixth expedition to this uninhabited island. Listen for KA1BB from 1300Z to 2000Z, General phone and CW, 2m SSB. QSL w/letter size SASE via Tri-City ARC, Box 686, Groton, CT 06340.

July 22: The Falls City ARC will operate K0JKS, 1300Z to 2300Z to commemorate the 4th annual Hot Air Balloon Extravanganza from Brenner Air Field in Falls City. Send 9x12 SASE and QSL to Bob Eis, WA0W, 1702 Fair Avenue, Falls City, NE 68355

July 22: The Reservoir ARA will operate K8QYL, 1300Z-2000Z July 22 and 1600Z-2000Z July 23 to commemorate the 20th anniversary of Neil Armstrong's walk on the moon. Operation will be from the Neil Armstrong Air & Space Museum in Wapakoneta, Ohio. General class bands, CW, SSB and RTTY. Novice SSB operation on 10m. For a certificate send QSL and No. 10 SASE to K8QYL, 1005 Linden Avenue, St. Marys, OH 45885-1327

July 23-27: The REACT ARC will operate a special event station in conjunction with the 2nd annual meeting of REACT ARC and the 14th annual convention of the REACT International. Lower 80, 40, 20m and 10m Novice. For certificate send 9x12 SASE and QSL to REACT ARC, c/o WB3FQY, POB 1033, Lancaster, PA 17603.

July 19-24: Fairbanks, Alaska. The Arctic ARC will operate special event station KL7KC, 0000Z July 15 to 0900Z July 24 in celebration of the discovery of gold by Fedrix Pedro in the Fairbanks area. For QSL card SASE to the Arctic ARC, PO Box 81389, Fairbanks, Alaska 99708.

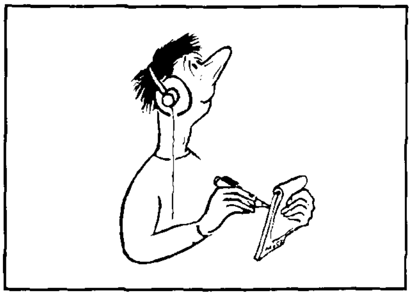
July 29-Aug 7. Eugene, Oregon. The Valley ARC will operate W7PXL 0100Z July 29 to 0100Z Aug 7 to commemorate the VIII world Veteran's Track and Field Championships. For QSL or certificate SASE to Valley ARC, PO Box 70314, Eugene, OR 97401.

LAUREL ARC monthly (except December) Amateur exam sessions for all license classes. No fee is charged. Pre-registration is required. Call (301) 725-1212, Maryland Radio Center, 8576 Laureldale Drive, Laurel, MD 20707

NORTH COAST ARC 1989 LICENSE EXAMS. 12:30 PM, Saturdays February 11, April 15, June 10, August 12, October 14, December 9. N. Olmsted Community Cabin, S of Lorain on W. Park. Novice thru Extra. Walkins allowed. Talk In 145.29 repeater. For information Dan Sarama, KB8A, 15591 Rademaker Blvd, Brookpark, Ohio 44142. 267-5083 or Pauline Wells, KA8FOE, Rick Wells, K8SCI, 777-9460/779-8999.

AMATEUR RADIO CLASSES: For those people interested in obtaining a Novice (basic level) Ham license or upgrading to Tech/General, the Chelsea Civil Defense, in cooperation with QRA Radio Club, will sponsor Amateur Radio Communications classes evenings at Chelsea High School starting MARCH 7, 1989. For more information write Frank Masucci, K1BPN, 136 Grove Street, Chelsea, MA 02150. Please enclose your telephone number.

THE MIT UHF REPEATER ASSOCIATION and the MIT Radio Society offer monthly HAM EXAMS. All classes Novice to Extra Wednesday, JULY 19, 7 PM, MIT Room 1-150, 77 Mass Avenue, Cambridge, MA. Reservations requested 2 days in advance. Contact Ron Hoffmann at (617) 484-2098. Exam fee $4.50. Bring a copy of your current license (if any), two forms of picture ID, and a completed form 610 available from the FCC in Quincy, MA (617) 770-4023



Garth Stonehocker, KØRYW

KNOW SPORADIC-E SKIP

As patches of Sporadic-E (E_S) ionization cross the United States — from southeast to northwest, for example — it's possible for short-skip and multiple propagation modes to exist on 6 meters. Surprisingly, they can be found occasionally on the 2-meter band. Openings appear quickly; they may stay in for just a few minutes, or remain open for hours. Sometimes in June or July DX signals may be heard around the clock. Signals can be received from distances of 500 to 1200 miles, and may at times be heard from distances as far away as 2500 miles on multiple hop paths.

How do you recognize such E_S openings? Suppose you're monitoring a beacon frequency and the band is quiet. Suddenly, you hear a build-up of "received noise." Almost instantly there are DX stations all over the band. Signal levels fluctuate rapidly as the session opens and as it declines. When the signal is there it usually pegs your S-meter, but it's also subject to rapid fades on the order of 60 dB or more that may chop it into a garbled mess.

George Jacobs, W3ASK, discussed one way to recognize the probable opening of E_S on 6 meters in the June 1962 issue of CQ. When you're on a lower frequency band, say 15 or 10 meters, listen to the stations being worked. If the minimum skip distance is decreasing, the skywave geometry is such that the maximum usable frequency (MUF) will be increasing by reflection from an E_S cloud (more dense than F2 and lower in height). W3ASK's rule of thumb states that when stations are heard less than 500 miles away on 10 meters, or less than 350 miles on 15 meters, the chances are good that 6 meters will open in that same direction.

A directional (not too narrow beam width) rotatable antenna with a low take-off angle is a definite advantage in finding and using the E_S short-skip propagation mode.

Last-minute forecast

The lower frequency bands (mainly nighttime DXing), will be best the first two weeks of July. Expected lower MUFs from a lower solar flux in those two weeks will raise signal strengths in the evenings to help overcome thunderstorm noise during those hours. The best low-band conditions will occur in the early morning hours. The higher band DXers will have to wait until the last two weeks of the month when long-skip openings with higher MUFs are expected. Geomagnetic disturbances are expected near the 6th and 16th, and on the 24th when they will be the most intense. Look for DX from unusual places on the disturbed days.

A full moon occurs on the 18th; perigee is on the 23rd. The Aquarids meteor shower begins on July 18th, peaks on the 28th, and lasts until August 7th. (All dates are approximate, but should be close.) The radio-echo rate at maximum is about 34 per hour.

Band-by-band summary

Six-meter paths will open for half an hour to a couple of hours on some days around local noon. Sporadic-E propagation will make this short-skip path possible out to nearly 1200 miles per hop.

Ten, 15, 17, 20, and 30 meters will support DX propagation to most areas of the world during the daylight hours and into the evening, with long skip out to 2000 miles per hop. Sporadic-E short skip will also be available on many days for several hours around local noon. The direction of propagation will follow the track of the sun across the sky: east in the morning, south at midday, and west in the evening. The longer period of daylight provides many hours of good DXing. Solar flux is high this year, so daytime absorption gives lower signal strengths than usual on these bands during this month.

Thirty, 40, 80, and 160 meters are the nighttime DXer's bands. On many nights, 30 and 40 meters will be the only usable bands because of thunderstorm QRN. Try the pre-dawn hours for best DX. The direction of propagation follows the darkness path across the sky: to the east in the evening, south around midnight, and toward the west in the pre-dawn hours. Skip distances will decrease to 1000 miles. Sporadic-E openings will be observed most frequently around sunrise and sunset. These may be the only signals getting through the noise in the evening. hr

JULY

WESTERN USA

GMT	PDT	N (Asia, Far East)	NE (Europe)	E (S. Africa)	SE (S. America)	S (Antarctica)	SW (New Zealand)	W (Oceania, Australia)	NW (Japan)
0000	5:00	12	18	15	10	10	10	10	10
0100	6:00	12	20	15	10	12	10	10	10
0200	7:00	10	20	18	10	12	10	10	10
0300	8:00	10	20	18	12	15	10	10	10
0400	9:00	12	20	18	12	18	10	10	10
0500	10:00	12	18	15	15	20	10	10	10
0600	11:00	15	15	10	15	20	10	10	10
0700	12:00	15	15	10	15	20	10	10	12
0800	1:00	18	30	12	18	20	10	12	15
0900	2:00	18	18	15	18	20	10	15	15
1000	3:00	18	18	18	18	20	12	15	18
1100	4:00	20	15	12	20	20	15	15	18
1200	5:00	18	15	10	15	30	15	18	30
1300	6:00	15	12	10	12	30	15	18	20
1400	7:00	15	12	10	10	30	15	18	18
1500	8:00	15	12	10	10	30	18	18	18
1600	9:00	15	10	10	10	30	20	18	30
1700	10:00	18	10	10	10	18	12	20	20
1800	11:00	18	10	10	10	15	10	20	18
1900	12:00	18	10	10	10	12	10	12	10
2000	1:00	20	12	10	10	12	10	10	10
2100	2:00	18	12	12	10	10	10	10	10
2200	3:00	15	15	12	10	10	10	10	10
2300	4:00	15	18	15	10	10	10	10	10

MID USA

GMT	MDT	N (Asia, Far East)	NE (Europe)	E (S. Africa)	SE (S. America)	S (Antarctica)	SW (New Zealand)	W (Oceania, Australia)	NW (Japan)	CDT
0000	6:00	12	18	15	10	12	10	10	10	7:00
0100	7:00	12	20	15	10	15	10	10	10	8:00
0200	8:00	15	30	18	10	15	10	10	10	9:00
0300	9:00	15	20	18	12	18	10	10	12	10:00
0400	10:00	15	18	18	12	20	10	10	12	11:00
0500	11:00	15	20	18	15	20	10	10	15	12:00
0600	12:00	18	20	15	15	20	10	10	15	1:00
0700	1:00	18	18	15	15	20	10	10	15	2:00
0800	2:00	20	15	18	15	20	10	12	15	3:00
0900	3:00	20	20	12	18	20	12	15	18	4:00
1000	4:00	18	18	12	18	30	15	15	18	5:00
1100	5:00	15	15	12	20	30	15	18	20	6:00
1200	6:00	15	15	10	15	30	15	18	30	7:00
1300	7:00	15	12	10	12	30	18	18	20	8:00
1400	8:00	12	12	10	10	30	18	18	18	9:00
1500	9:00	12	12	10	10	30	20	18	20	10:00
1600	10:00	10	10	10	10	20	20	20	18	11:00
1700	11:00	10	10	10	10	18	12	20	18	12:00
1800	12:00	12	10	10	10	15	10	20	15	1:00
1900	1:00	15	12	10	10	15	10	12	15	2:00
2000	2:00	18	15	10	10	12	10	10	12	3:00
2100	3:00	18	15	12	10	12	10	10	12	4:00
2200	4:00	20	18	12	10	12*	10	10	10	5:00
2300	5:00	15	18	15	10	12	10	10	10	6:00

EASTERN USA

GMT	EDT	N (Asia, Far East)	NE (Europe)	E (S. Africa)	SE (Caribbean, S. America)	S (Antarctica)	SW (New Zealand)	W (Oceania, Australia)	NW (Japan)
0000	8:00	15	15	15	10	15	10	10	10
0100	9:00	12	15	15	10	15	10	10	10
0200	10:00	15	40	18	10	18	10	10	12
0300	11:00	15	20	18	12	20	10	10	12
0400	12:00	18	18	18	12	20	10	10	15
0500	1:00	18	18	18	15	20	10	10	15
0600	2:00	20	30	15	15	20	10	10	18
0700	3:00	20	20	15	15	20	10	10	18
0800	4:00	18	18	18	18	20	12	15	20
0900	5:00	15	15	12	20	30*	15	15	18
1000	6:00	15	15	10	15	30	15	20	15
1100	7:00	12	15	10	12	30	15	18	15
1200	8:00	12	12	10	10	30	15	18	15
1300	9:00	10	12	10	10	30	15	18	15
1400	10:00	12	12	10	10	30	18	18	15
1500	11:00	12	12*	10	10	30	18	18	18
1600	12:00	15	12*	10	10	20	18	20	20
1700	1:00	15	12	10	10	15	12	20	18
1800	2:00	18	12	10	10	15	10	20	15
1900	3:00	18	12	10	10	15	10	10	15
2000	4:00	18	12	10	10	15	10	10	15
2100	5:00	20	12	12	10	15*	10	10	12
2200	6:00	18	15	12	10	15*	10	10	12
2300	7:00	15	15	15	10	15	10	10	10

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NEW HAM RADIO

hr

Special
CQ WW DX Phone Contest
Record-breaking effort!

This month...

Vibration Induced Yagi Fatigue Failures

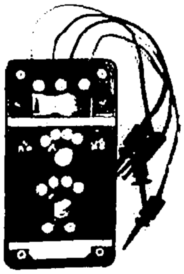
Versatile Transistor/Diode Tester

High Performance Duoband Yagi for 15 and

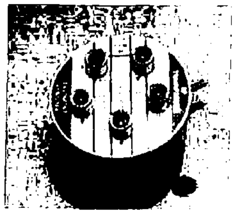
Plus, all your favorite monthly features!

HAM RADIO

AUGUST 1989
Volume 22, Number 8



W5JQE, page 30



K4IPV, page 71

On the Cover: Cushcraft HF and VHF antennas set against a late September sky at the QTH of WA1QFY.

See page 79 for the *Ham Radio* Magazine 1988-89 Sweepstakes Winners List.

FEATURES

DEPARTMENTS

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Ode to the Death of PRB-3

When PRB-3, the bill to allow special callsigns, was first announced I was overjoyed at the prospect of being able to get a coveted 1x2 callsign. No longer would I be asked if I belonged in the Extra part of the band. I could rightfully join my Extra class brethren as ?1??! Or so I thought.

I have never been overly attached to any of the three calls I've had. As a Novice, WN1IGG wasn't bad, but the phonetics were horrible — Weston's Number 1, I Go Goofy. Gratefully, I never went on the General bands with that one. When I finally passed the General in 1972, the FCC gave me WA1QWW. Now there was a call you could be proud of — WA1 Quarter Wave Whip. There was a nice ring to it on CW too. However, I was still searching for the "perfect" call. In 1978, it was time to move on and get my Advanced. Did I want a new call? Surely, I didn't want KA1sumthinorother. Group C calls sounded good, so I ended up with N1ACH.

When I got to HR in 1979, I felt duty bound to upgrade to Extra in keeping with our high tech image. It wouldn't look good for me to have *just* the Advanced. Sooooo, I got my Extra. But for some reason, I didn't put in for a callsign change. Maybe the 2x1's at the time didn't have enough pizazz to me.

That all changed when PRB-3 was announced. Whoopee! Now I can get the call I want. What would I get? I really liked the W1X series of calls. So, I went through the list to see what was available. Jim Kearman had let W1XZ go. That had a nice CW ring to it. So did a few others. But I felt I'd be taking someone else's property.

Then it hit me.

What better call to ask for than W1HR, Jim Fisk's old call. Now this call has pizazz! I felt it would be a fitting tribute to Jim's memory to carry on his call here at *HR*. Contests and DX circles would ring again with the familiar W1HR call. Could I get it? Would someone else beat me to the punch?

Getting ready for the FCC to implement PRB-3, I figured I would either FAX, FedX, or maybe even hand carry an application to the authorized "giver of callsigns." This was an opportunity I wasn't going to miss. I wanted W1HR so bad I could almost taste it.

At the Dallas ARRL 75th Anniversary Convention in June, the FCC announced that they had killed PRB-3. This dashed my hopes of ever getting that super special callsign I've been waiting for, once and for all. It also means that, unless there is a major change in the FCC, expired calls will never again be reissued. There are plenty of us who would be happy to reactivate those calls — but 'tis never to be.

Well one cannot be disappointed forever. Now I'm playing the waiting game for the next best thing — NX1?. If I time it right, mebbe I'll get NX1H. It's a roll of the dice at best, but it's all I have left to get that "special" callsign.

de NX1? dba N1ACH

Comments

Learning CW a "plus" for all hams

Dear HR

Concerning the no-code proposal: I feel that some opposition should be laid out to avoid dangers to the Amateur Radio service. Some of the problems created by having no code as an enticement into the Amateur Radio ranks are as follows:

Having a lack of CW knowledge in a state of emergency can prove disastrous. The no-code proposal, if passed, will let flocks of hams into the VHF and UHF ranks. This may be nice for a while, but then it will be proposed for the HF ranks. Pretty soon, CW itself will be the "obsolete language" of ham radio.

Eliminating the code test makes a mockery out of all the hams who have studied so hard to join the elite ranks of Amateur Radio in the first place. New young hams? Why is the code so hard for them to learn? It seems to me that the complaints stem from the older hams who just can't grasp the language. I was licensed all the way to Extra by the time I was 13 years old.

Pointing to CW as a learning block for all of the new hams is absolutely wrong. Come on! How about all of the new computer programmers who want to get onto radio? Anyone who can program those machines of splendor and strength should be able to pass a CW test.

The problem of slowing Amateur Radio growth stems from the older, experienced hams not getting the new ranks involved. Walking down a city street, probably only 5 in 20 people know what ham radio really is! Let's get on our feet and wave the Amateur Radio banner.

Instead of standing around arguing whether we should pass a CW test or not, let's pass out the code tapes and get rolling! I have five new friends who are getting their licenses soon, CW capable of course. See you on the bands, CW no doubt!

John Muhr, KT0F,
Littleton, Colorado

Preservation — our right

Dear HR

The late great Radio Amateur, Col. Clair Foster, W6HM (who personally paid for the first state-of-the-art ARRL headquarters station, W1MK), used to stress an argument that strongly calls for retention and expansion of our ham bands:

"They are like our national parks," he said. "They provide for the exercise of a valuable national talent (see Sec. 1 of the FCC rules). We don't log our national parks, do we? Taking ham frequencies for commercial use should not be permitted any more than the despoiling of our national parks for profit."

Louis R. Huber, W7UU,
Seattle, Washington

A tradeoff

Dear HR

I just read Bill Orr's "What is the correct radial length?" portion of April's Ham Radio Techniques. Bill surmised that radial length as compared to wavelength may not be critical in the HF spectrum. I have to agree, since I often wondered just exactly what people mean when they refer to "resonant radials." Are there things? I didn't think that radial's exhibit any reactive characteristics which are necessary to qualify as a tuned circuit. Isn't the primary objective to reduce ground resistance as much as possible in order to capture the greatest amount of displacement currents?

When reading many of the antenna books one might assume that if you're constructing a multiband vertical for HF you should cut radials at different lengths for the different bands. Not so, bury as many as you can and as long as your pocket book can afford. The impact on SWR should be dealt with *after* obtaining the highest efficiency possible. New hams would be well advised that a higher SWR due to an increase in length or number of radials is not indicative of a poor system. It simply means that since you have decreased ground resistance which results in increased efficiency, you must change *something* in the system that will "rematch" the transmission line and antenna.

Patrick Bouldin, KM5L,
Lancaster, Texas

Better management of HF bands needed

Dear HR

Enough is enough. I've been involved with ham radio for about 25 years. I spend all my radio time on the HF bands, especially 20 and 10. The atrocities that take place nowadays are demoralizing and the list is long: people tuning up on QSOs, running a carrier on DX, contacts on contacts as if 500 kc wasn't close enough, calling CQ without checking for a clear frequency first, deliberate malicious interference, not giving consideration to phone nets, RTTY on phone QSOs, etc. Even on CW some of the same problems exist.

It used to be the **first** time you did something wrong you received a letter from the FCC. Nowadays, nobody worries because they know that nothing is going to happen to them. After recent calls to my local FCC office and section manager I find this to be unfortunately true. I think it's time to admit that the Amateur community is not capable of handling the job of self-policing. If it comes down to the point where the FCC can't do the job because of money, then we're doomed to be no better off than the CBers.

Glenn Durant, KB0BHN,
Firestone, Colorado

VIBRATION INDUCED
YAGI FATIGUE FAILURES

By Dick Weber, K5IU, Box 44, Prosper, Texas 75078

Yagi element failure can be attributed to two basic causes. The first type of failure occurs when an element isn't strong enough to hold up when forces are applied. These forces may be caused by a thick layer of ice, high winds, or a combination of the two. Under the stress of these forces, the element either bends or breaks off, with signs of bending in the area of the break.

The second type of failure takes place after an element has been fluttering, or vibrating, in a relatively low wind stream. The break caused by this kind of failure is quite different. There's no sign of bending in the area of the break; it's a jagged line through the element. In addition to element fluttering, boom fluttering (although not as common) can lead to the same failure.

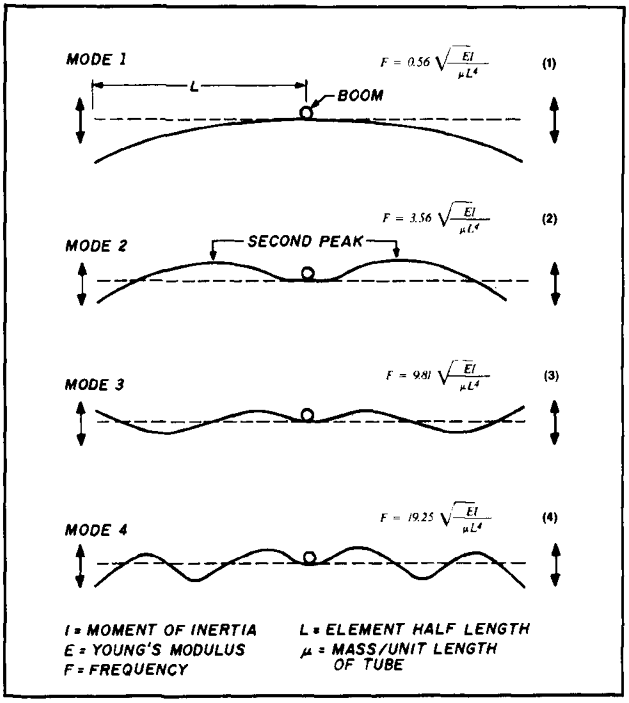
Because there's no sign of bending you'll know that the stress levels in the material are relatively low, yet failure occurs. What causes an element to flutter in the wind? What causes a break although the stress levels are well below those required to bend the tube? And what methods will minimize or eliminate this type of failure?

Understanding flutter

Two key areas that must be explored to understand flutter are the vibratory aspects of the element and the forces that set it in motion.

An element has mechanical resonant frequencies which can be excited. **Figure 1** shows four modes of element vibration and the shape the element takes during oscillation in each mode. These resonant modes happen at discrete, not harmonically related, resonant frequencies. The element has stiffness and mass — the necessary ingredients for resonance. The modes are different situations where the ingredients blend properly to yield resonance. There's a separate resonant frequency with each mode. This means the element can have several resonant frequencies. Use the equations shown with each mode in **Figure 1** to calculate the resonant frequency for that mode. **Equations 1** through 4 are for an element made of one tubing size.[1] Finding resonant frequencies for elements constructed of telescoped sections is best handled by computer finite element structural analysis programs. You can make approximations with the equations shown by selecting a tube diameter the same as the second or third smallest in the element. **Table 1** shows the resonant frequencies for various lengths and sizes of tubing for the first four modes. (Telescoped elements will have resonant frequencies in the ranges shown in **Table 1**.)

FIGURE 1



The four possible modes of element oscillation.

The mechanical resonances are lightly damped. Their behavior is exactly like high Q resonant electrical circuits. As a result, small exciting forces cause large displacement oscillations. For this to happen, and for flutter to be established, there has to be an exciting force at or very near one of the mode resonant frequencies. In addition, the excitation must be maintained to sustain the element oscillation. Where does this excitation come from? How can a mild wind stream provide a vibratory input to initiate and maintain an element oscillation?

Wind excitation

Several things can occur when air flows over a round tube. At low wind speeds nothing happens. The air flows around the tube creating no disturbances of any kind. At higher wind speeds, the air can't cling to the back side of the tube. This creates vortices, or swirls of air. At first the vortices form in pairs coming from both edges of the tube.

TABLE 1

Resonant frequencies of the first four modes for various element configurations.

Element Tube Diameter (inches)	Half Length (inches)	Wall Thickness (inches)	Mode 1 (Hz)	Mode 2 (Hz)	Mode 3 (Hz)	Mode 4 (Hz)
0.500	100	0.058	1.2	7.9	21.8	42.6
0.625	100	0.058	1.6	10.0	27.8	54.5
0.750	100	0.058	1.9	12.3	33.8	66.4
0.875	100	0.058	2.3	14.5	39.9	78.3
0.500	135	0.058	0.7	4.3	11.9	23.4
0.625	135	0.058	0.9	5.5	15.2	29.3
0.750	135	0.058	1.1	6.7	18.6	36.4
0.875	135	0.058	1.2	7.9	21.9	42.9
1.000	135	0.058	1.4	9.2	25.3	49.5
0.625	200	0.058	0.4	2.5	6.9	13.6
0.625	200	0.116	0.36	2.3	6.4	12.5
0.750	200	0.058	0.5	3.1	8.5	16.6
0.750	200	0.116	0.45	2.9	7.9	15.4
0.875	200	0.058	0.6	3.6	10.0	19.6
0.875	200	0.116	0.5	3.4	9.4	18.3
1.000	200	0.058	0.7	4.2	11.5	22.5
1.000	200	0.116	0.6	3.9	10.6	21.3
1.125	200	0.058	0.75	4.7	13.0	25.5
1.125	200	0.116	0.7	4.5	12.4	24.3
1.250	200	0.058	0.83	5.3	14.5	28.2
1.250	200	0.116	0.79	5.0	13.9	27.2

FIGURE 2

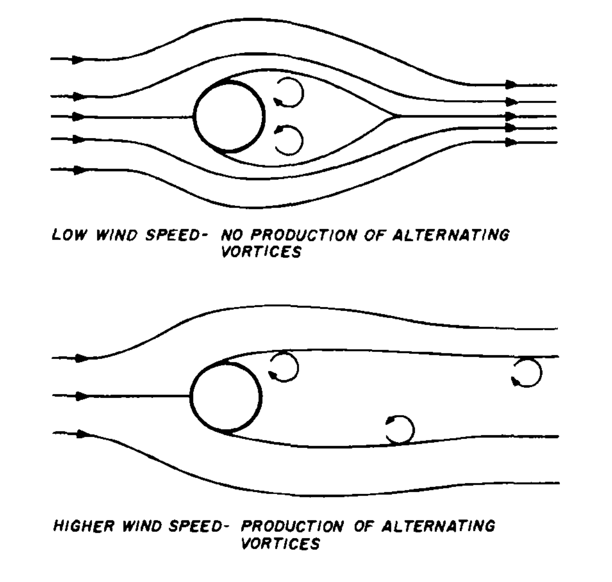


Diagram showing the cause of oscillation due to the creation of alternating vortices.

As the wind speed increases, the vortices leave first one edge of the tube and then the other. The formation of the vortices alternates back and forth between the two edges. The result is an oscillatory pressure loading on the tube. When the frequency of vortex formation is the same as the resonant frequency of one of the element vibratory modes, the element begins to flutter. **Figure 2** shows the various stages of vortex shedding.

As the wind stream velocity increases, the frequency of vortex formation accelerates. When the frequency of the vortex shedding builds up sufficiently, the element stops vibrating because the excitation is not at, or near, a mode resonant frequency. Similarly, as the wind speed decreases, either vortices cannot be shed or the frequency of shedding drops below a mode resonant frequency. The result is the same: the element stops vibrating.

As the wind speed continues to increase, vortices continue to be produced, but with greatly diminished amplitude. No effective excitation is produced above a certain air velocity. The result is a range of possible frequencies that can excite an element. The element will flutter only if the wind sheds vortices from the tube at or near an element mode resonant frequency.

Use **Equation 5** to find the shedding frequency.[2] The term Nr is an important parameter; it determines the interplay of the tube size, air velocity, air density, and air viscosity. Shedding occurs when Nr is in the range of 60 to 10,000.[3] Although shedding can occur over this wide range of Nr, other conditions may not be suitable for the initiation of element flutter.

$$f = 3.52 \cdot \frac{V}{D} \cdot \left[1 - \frac{20}{Nr}\right] \qquad (5)$$

$$Nr = 774 \cdot V \cdot D \qquad (6)$$

f = frequency of vortex shedding (Hz)
V = wind velocity (mile/hour)
D = tube diameter (inches)
Nr = Reynolds number (dimensionless) (air parameters factored into coefficient)

TABLE 2

Wind and frequency ranges for vortex shedding

Tube size (inches)	Wind speed range (mph)	Frequency range (Hz)
0.250	0.30—52	2.8—730
0.375	0.20—34	1.4—318
0.500	0.16—26	0.8—182
0.625	0.13—21	0.5—118
0.750	0.10—17	0.3—80
0.875	0.09—15	0.2—60
1.000	0.08—13	<0.2—46
1.125	0.07—11	<0.1—34
1.250	0.06—10	<1.1—28

Table 2 shows the wind speed ranges for tube sizes having the correct Nr range. There's no reason to consider wind speeds out of these ranges for a particular tube size when using **Equation 5**. This means that for the tubing sizes used in a Yagi element there's an upper and lower boundary to the frequencies which may start fluttering. If an element is made of several diameters of tubing, the upper and lower shedding frequencies are determined by the smallest and largest diameter tubes, respectively. **Table 2** also lists the range of shedding frequencies for each tube size. The possible frequency range is, theoretically, extremely wide.

The extremely low wind velocities within the range of Nr offer little danger. There's generally insufficient energy in the wind stream to cause pressure loadings of any appreciable magnitude on the tube. In addition, at higher wind speeds the flow is so turbulent that the vortices don't all shed from one side of the tube and then the other. They come off the tube at about the same frequency, but not in an orderly fashion.[3]

What then is the proper range of wind speeds which can cause fluttering? My own experience and observations have been of wind speeds less than 35 mph. This still leaves a wide range of frequencies that can be generated by vortex shedding. I've seen many elements vibrate in mode 2 and several vibrate in mode 3. I've also seen elements vibrate at a fixed frequency even though the wind speed wasn't constant. This indicates that a broad band of frequencies can be generated by vortex shedding from the same element, not only because of multiple element diameters, but also because the shedding frequency isn't inherently stable. I have never seen mode 1. Either there's insufficient energy in the wind stream at these wind speeds, or the vortices detach themselves when the element begins to vibrate, and the element shuts itself down.

The possible range of exciting frequencies in **Table 2** shows that these frequencies are in the range of the resonant frequencies of the various tube configurations in **Table 1**. Don't consider the lower frequencies in **Table 2** too seriously; there's a very small level of energy in the corresponding wind streams. It also appears that elements should begin vibrating in any wind stream. In reality, this doesn't happen. Even in view of the anomalies, you can gain insight into the vibratory behavior of a fluttering element.

Element fatigue failure

An element that breaks as a result of sustained fluttering fails by a different mechanism than if it bends due to a very high force. When an element bends or breaks off because of a very high wind or ice load, the yield stress of the material has been exceeded. An element can be deformed by a force below the yield stress, but when the force is removed the element will return to its original starting point. For example, if you pull a Yagi element with your hand, it will deflect several inches. When you let go, the element will return to its original shape. If you pull on the element enough to give it a permanent bend, you have stressed the material above its yield stress. Therefore, exceeding the yield stress results in a permanent bend. If the yield stress is greatly exceeded, the element will first bend and then break. An element which fails due to fluttering breaks for a different reason.

When aluminum is flexed at levels below the yield stress, no permanent bend results but damage accumulates. If the flexing is repeated enough times, the accumulated damage in the material results in a fatigue failure. The higher the load, the less load applications are needed to give a fatigue failure. The lower the load, the more cycles of application are needed to create the same accumulated damage. When an element flutters long enough, the accumulated damage in the material gets to the level where the element suffers fatigue failure.[4] However, there's no sign of a bend or evidence indicating the material has exceeded its yield stress near the break.

Minimizing element failure

There are several things that can be done if an element flutters. You can attempt a modification to the element to limit the amplitude of the stress during fluttering. Try increasing damping in the element to extend its life. This will lower the Q of the mechanical resonance, which means that the tube will take many more load cycles to generate a failure. I've heard of people filling the inside of elements with foam intended for sealing and insulating cracks and holes in buildings. This method may work. But if you attempt this, take two identical elements and foam only one. After the foam has cured, shake both of them in your hand to see if there is an appreciable difference in how the element vibrates when excited. Shake the element to set up a mode 2 oscillation (see **Figure 1**). Once you have oscillation, stop moving your hand and see how long it takes for the element to stop shaking. If the foamed one damps out sooner, you may have a working solution.

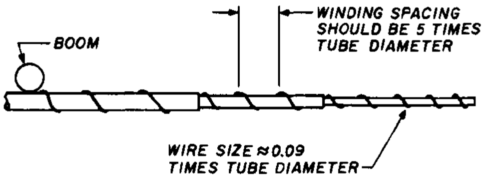
You might also modify the shape of the element so that orderly vortices can't be shed. To do so, wrap a wire in a helix around the element.[5] The wire diameter should be

TABLE 3

Resonant frequencies of the first four modes with 1/2" rope for various element configurations

Tube diameter (inches)	Element half length (inches)	Wall thickness (inches)	Mode 1 (Hz)	Mode 2 (Hz)	Mode 3 (Hz)	Mode 4 (Hz)
0.500	100	0.058	1.15	7.3	20.1	39.5
0.625	100	0.058	1.5	9.5	26.1	51.3
0.750	100	0.058	1.8	11.7	32.2	63.1
0.875	100	0.058	2.2	13.9	38.2	74.9
0.500	135	0.058	0.6	4.0	11.0	21.6
0.625	135	0.058	0.8	5.2	14.3	28.1
0.750	135	0.058	1.0	6.4	17.6	34.6
0.875	135	0.058	1.19	7.6	20.9	41.1
1.000	135	0.058	1.38	8.8	24.3	47.7
0.625	200	0.058	0.37	2.4	6.5	12.8
0.625	200	0.116	0.35	2.2	6.1	12.0
0.750	200	0.058	0.45	2.9	8.0	15.7
0.750	200	0.116	0.43	2.8	7.6	14.9
0.875	200	0.058	0.5	3.5	9.6	18.7
0.875	200	0.116	0.5	3.3	9.1	17.9
1.000	200	0.058	0.63	4.0	11.0	21.7
1.000	200	0.116	0.59	3.86	10.58	20.8
1.125	200	0.058	0.71	4.6	12.6	24.7
1.125	200	0.116	0.69	4.4	12.2	23.8
1.250	200	0.058	0.80	5.1	14.1	27.7
1.250	200	0.116	0.77	4.9	13.7	26.8

FIGURE 3



Experimental method for eliminating the creation of vortices by wrapping the elements with wire.

about 0.09 times the diameter of the element with the turns of the helix spaced about 5 times the diameter. (See Figure 3.) I don't know if anyone has tried this approach. I plan to experiment with it and I hope others will too. It offers the possibility of being the best solution. Rather than trying to accommodate the production of vortices, this approach may eliminate their generation. I know this idea has been applied successfully to various types of structures, like suspended pipelines and smoke stacks, but I'm not aware of its use with Yagi elements.

You can attempt to retune the mechanical resonances of the element out of the range of vortex shedding frequencies in two ways. One traditional method is to use damping ropes inside the elements. Actually, damping ropes provide both a slight mechanical retuning of the element and the addition of some amount of damping to lower the Q of the mechanical resonance. My experience with damping ropes has shown them to be of little value. I had four fatigue failures on a 20-meter Yagi and three on a 10-meter Yagi in one year. All had ropes. After the first break on each, I changed the ropes to the largest possible size, with no success.

The amount of mechanical retuning that results from placing a rope inside an element is shown in Table 3. I've calculated the resonant frequencies with a 1/2-inch rope inside the entire element length. A comparison of Table 1 and Table 3 shows the resonant frequencies haven't been substantially altered. If anyone has had success with ropes, it probably has been due to a lowering of the Q of the mechanical resonance by providing some damping. This was probably a marginal case. Evaluate this method the same way you did the foamed elements. Perhaps you can enhance the damping provided by the rope by gluing its entire length to the inside of the element. You'll probably have to soak the rope in an adhesive and coat the inside of the element before pulling the rope through.

A weight fastened to the tip of an element can alter the resonant frequency appreciably. Table 4 shows the same element configurations, with a 3-ounce weight at the element tip. This table compares the first mode with and without the weight. There has been about a 40-percent reduction in resonant frequency. The second mode resonant frequency will be reduced further, while the higher modes' resonant frequencies will increase. I tested this on a 20-meter Yagi element and found that adding a 3-ounce weight cut the second mode frequency in half. The degree of retuning depends on element configuration and weight size.

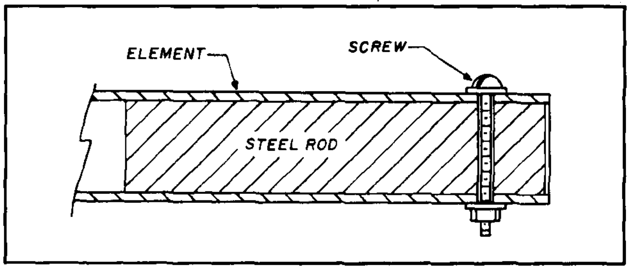
Several years ago Dennis Peters, N5UA (now deceased), had a 10-meter beam which was losing an element about every two months even though he had ropes in the elements. After some discussion and much frustration on his part, he added weights to each element tip. Dennis used large washers secured with hose clamps; they did the trick.

TABLE 4

Resonant frequencies of mode 1 without and with a 3-ounce tip weight.

Tube diameter (inches)	Element half length (inches)	Wall thickness (inches)	Mode 1, no tip weight (Hz)	Mode 1, with tip weight (Hz)
0.500	100	0.058	1.2	0.7
0.625	100	0.058	1.6	1.0
0.750	100	0.058	1.9	1.27
0.875	100	0.058	2.3	1.51
0.500	135	0.058	0.7	0.44
0.625	135	0.058	0.9	0.57
0.750	135	0.058	1.1	0.70
0.875	135	0.058	1.2	0.84
1.000	135	0.058	1.4	0.97
0.625	200	0.058	0.4	0.27
0.625	200	0.116	0.36	0.25
0.750	200	0.058	0.5	0.33
0.750	200	0.116	0.45	0.31
0.875	200	0.058	0.6	0.39
0.875	200	0.116	0.5	0.37
1.000	200	0.058	0.7	0.45
1.000	200	0.116	0.6	0.43
1.125	200	0.058	0.75	0.51
1.125	200	0.116	0.7	0.49
1.250	200	0.058	0.83	0.57
1.250	200	0.116	0.79	0.55

FIGURE 4



Adding weight to reduce the mechanical resonant frequency.

The antenna suffered no failures in the year before his station was dismantled.

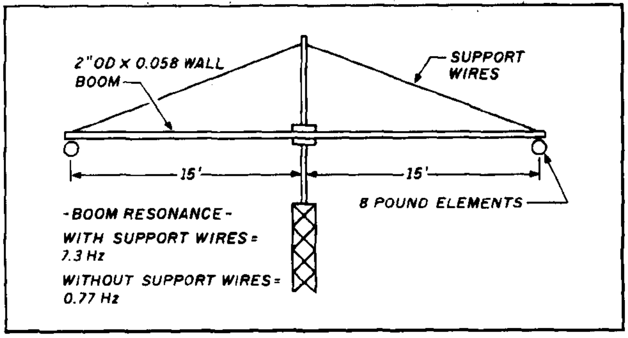
Add weights by clamping them to the outside of the element or securing them to the inside. You can slip lengths of steel rod into the tip of an element and secure them with screws. (**Figure 4** shows this method of attachment.) If you add weights, they can't be taped to the element. They must be hard mounted.

There are two preferred locations for adding weights. The first is at the tip. Another spot is about one-fifth of the way from the tip to the boom. The tip moves the most in modes 1 and 2; the second location moves substantially in mode 2. Adding weights loads these locations for the most dramatic retuning. Observe the shape the element takes when it's fluttering in order to determine weight placement. You'll see a displacement peak at the tip, and another part way to the boom. Put the second weight at the second peak. In **Figure 1**, the second peak is labeled for mode 2.

Boom flutter

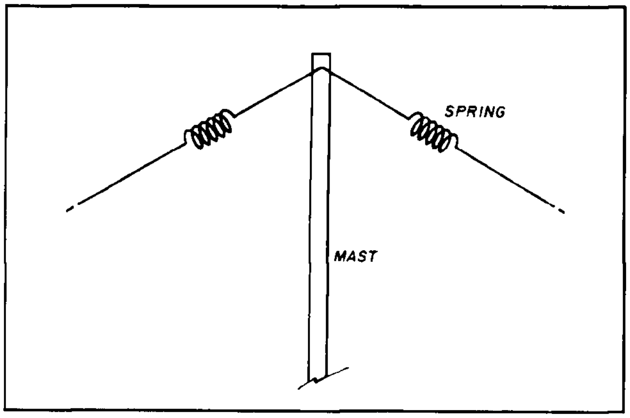
I've seen booms fluttering on several occasions. One boom eventually failed at the mast end. This failure isn't as common as element flutter, but it does happen. The cases I've observed have all had boom support wires strung from the mast to the boom. For the boom in **Figure 5**, the resonant frequency with the support wires is 7.3 Hz. Without the support wires, the resonant frequency is 0.77 Hz. Getting rid of the wire drops the resonant frequency substantially, but a lack of support wires may not be acceptable. Fortunately, there's an easy solution to the problem. The key is to provide the support needed, but not the stiffness of the support wire. Install a spring in the support wire as shown in **Figure 6**. The softer the spring the better. Pick a spring, or series of springs, that won't be stretched excessively by the tension needed to support the boom. This will

FIGURE 5



Case where boom with support is more prone to flutter.

FIGURE 6



Installing stiff springs in the boom support lines to damp the resonant frequency.

decouple the stiffness of the support wire and still provide the needed tension. The shift in resonant frequency will most likely put the boom into an area where either the energy in the wind stream isn't sufficient to start flutter, or the boom resonant frequency is below the vortex shedding minimum.

Element design variations

I've had Yagis with severe fluttering problems. I've also had Yagis with no problems at all. Those having failures were very stiff when compared with their mass, while those that had no damage weren't as stiff when compared with their mass. In **Equations 1** through **4**, the term $\frac{EI}{u}$ appears. EI is a stiffness term, and u is a mass term. The lower the "stiffness to mass" ratio, the lower the mode resonances. Based on the Yagis I have owned, I've concluded that elements with the lower resonant frequencies have the best chance of not fluttering. This suggests that retuning the element is indeed a viable approach, a fact supported by the experiences of Dennis Peters. I'd be very interested in hearing from any readers who have experienced problems with fluttering elements, whether you've been successful at solving them or not.

Summary

Elements and booms have mechanical resonant frequencies which can be put into oscillation by vortices shedding from the tube edges. There are several ways to reduce the likelihood of a fatigue failure. Damping can be added to reduce the amplitude of the stress. This would lengthen the life of the element. Adding damping ropes may help in marginal cases. Other methods have been tried, and there is certainly room for innovation. You can test an idea on the ground to see if it will reduce the Q of the mechanical resonance by noting the time it takes for oscillatory motion to damp out.

The most promising approach for minimizing element fatigue failures is to eliminate the orderly generation of vortices. The orderly formation of vortices will be disrupted in an element which is helically wound with a wire. To the best of my knowledge, this approach hasn't been tried with Yagis. It may prove to be the most effective remedy for fluttering elements.

There's a successful approach that's been used to eliminate element fatigue failures. Retuning the resonant frequencies of an element offers a means to prevent fatigue failure by moving the element resonances out of the shedding frequency range. You can do this by adding small weights. At minimum, the weights should be added at the element tips. A second location is on the span of the element, at the point with the largest displacement during a mode 2 oscillation. In addition, when selecting or designing a Yagi, keep in mind that elements which aren't very stiff in relation to their mass are less prone to vibration-induced fatigue failures.

Yagi booms are also subject to vortex shedding and fatigue failures. Booms with support wires have been observed to be most prone to fluttering. You can retune a boom with support wires by the adding springs in line with the wires. This lowers the resonant frequency of the boom and prevents it from fluttering. hr

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THE BATTLE OF THE BEAMS
PART 2

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As early as 1934, when *Knickebein* was in its infancy, a German scientist began to have doubts about its efficiency if exposed to jamming. He was Staatsrat (Privy Councillor) Dr. H. Plendl of the Deutsche Versuchanstalt für Luftfahrt (German Aeronautical Research Establishment) and he began to produce designs for a new system for accurate blind bombing.

Under his leadership, a new department was formed at Rechlin (the German equivalent of Farnborough) which began research in June of that year. This was in cooperation with another department led by a Dr. W. Kühnold which was also engaged on beam techniques for blind landing. The beams of Kühnold's system, however, had an aperture angle of about 5°, corresponding to an 8-km beamwidth at a range of 100 km, and were clearly unsuitable for accurate pinpointing of targets. Obviously a beam width of not more than 0.1° was required and this (at that time) could be attained with reasonable antenna dimensions and suitable power only if a frequency between 66 and 77 MHz were employed. Accordingly, experiments were begun with an 80-watt transmitter designed by a Dr. Ochmann which was code named *Bertha 1*; as this was not powerful enough a second was designed, *Bertha 2*, which delivered 500 watts and was tunable over the required range.

Preliminary tests carried out over Lake Müritz near Mecklenburg in 1935 resulted in ranges of only 1500 meters. Stationary beam antennas which could be phased to swing through about 10° were used, and the airborne equipment consisted of two t.r.f. receivers developed at Rechlin and an analyzer for unlocking the 2000-Hz modulated dot/dash system of the adopted and improved Knickebein apparatus. Unfortunately, full details of both transmitter and receivers are no longer available.

Wotan 1

By 1938, the system had been greatly improved. Dr. Kühnold had developed ground installations capable of easy dismantling and removal, with an operating cabin and antenna array mounted on a platform which could rotate through 360°. The antennas were mounted on a gantry and spaced at 14.75 meters (3.5 wavelengths). Originally, simple half-wave dipoles were employed, but before long directors and reflectors were added for extra power and range; these were energized with pulses at 120 per minute via a vacuum switch (soon replaced by a capacitor, nicknamed a "mill switch," designed by Dr. K. H. Fischer). The schematic block diagram of this system is shown in **Figure 1**. A half-wave Lecher line is used in conjunction with the "capacity" switch and its associated inductances to pulse both dipoles with the required dot/dash sequence.

The array generated a fan of 14 beams each with a bandwidth of 0.05° (**Figure 2**), and eight of these installations were erected in Germany, followed by many more on the coasts of occupied Europe. By now the airborne equipment had also been drastically improved by Dr. H. Hanel and Dr. Rücklin Telefunken, who had designed and developed a superhet for 66 to 77 MHz (code named *Anna*), while an analyzing system designed by Dr. Plendl known as the AVP (Anzeige-Verfahran von Plendl) was being mass-produced by Siemens.

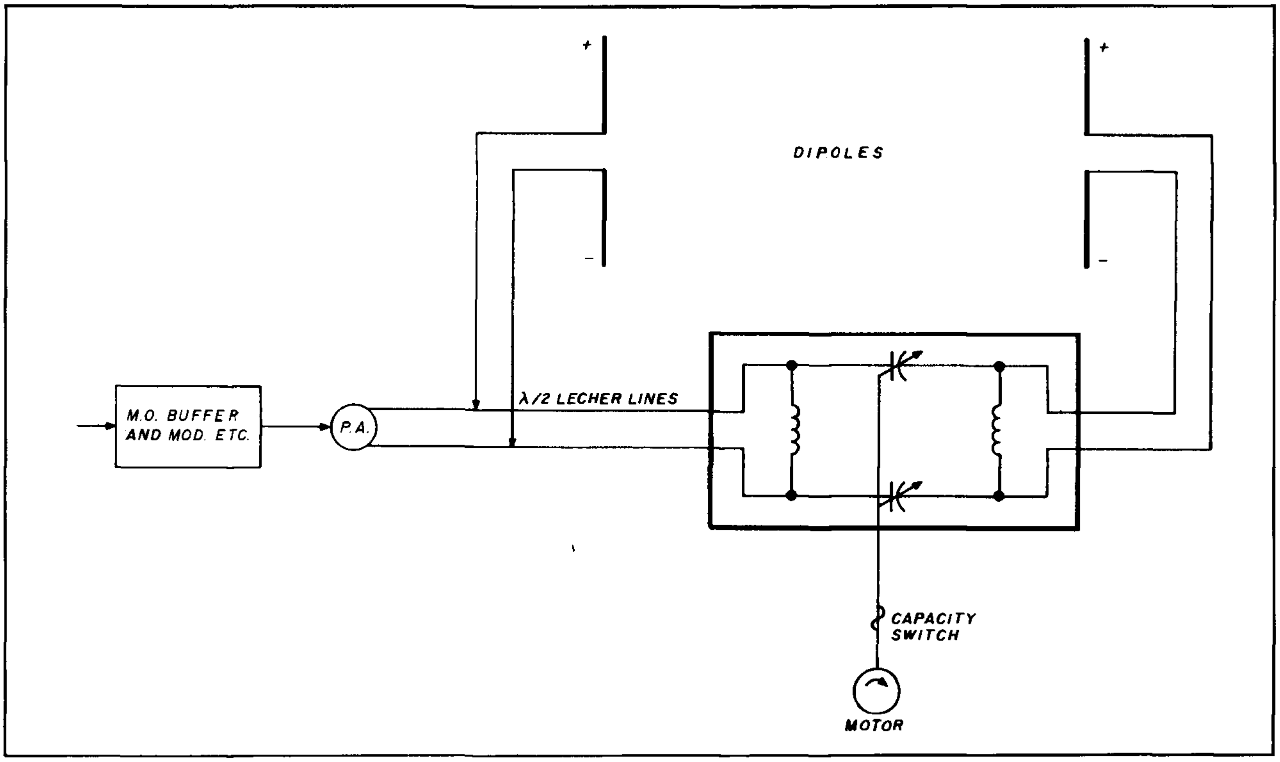
At the same time a Dr. K. Müller set up a Mobile Research Unit which produced some versatile mobile stations under the code name *Möbelwagen* or "furniture vans." He was also responsible for the clever camouflaging of their antenna — a feature which was later to prove troublesome for British counterattacks.

The complete system was known as *Wotan 1*.

Principle of operation

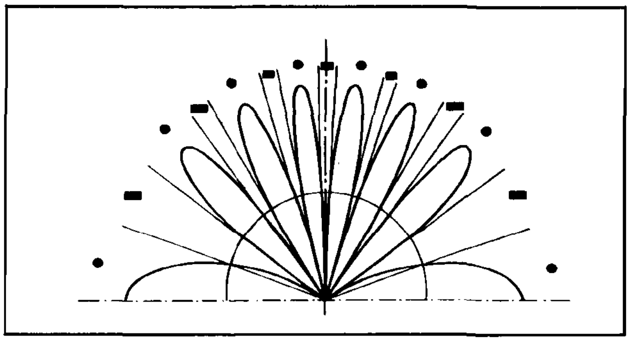
One of the 14 beams was selected to act as a director beam which, on being aimed towards the target, provided a flight path for the aircraft; this system was similar to Knickebein in that the pilot could plot his course according to a direction-indicating meter which told him if he was to the right or left of the beam. The official German layout of the beam-approach system and its associated cross-beams at points before the target is shown in **Figure 3**. **Figure 4** represents not only the director beam and reserve beam, but also the cross-beams and the associated fans of beams which enabled stray aircraft to plot their courses to the correct one. The main beams of the system used for the devastating raid on Coventry in 1940 are shown in **Figure 5**, and **Figure 6** is another official German layout showing

FIGURE 1



Block diagram of X-Gerät feed system and capacity switch for pulsing.

FIGURE 2



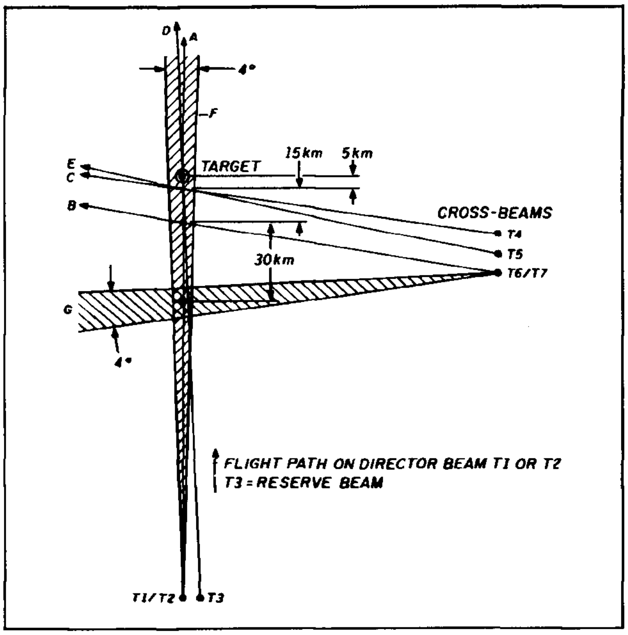
Antenna pattern of X-Gerät system.

the disposition of all beam systems in use at that time. (In this series the author has concentrated only on the more widely known systems.)

In practice the bombers did not fly along the director beam immediately after takeoff, but used either normal navigational methods or one of the fan beams, in order to present a smaller target for British radar and to try to cause confusion. The director beam was usually joined sometime after crossing the English coast.

At approximately 30 km before the target, the aircraft would encounter the coarse advanced cross-beam which, like the other beams, was similarly pulsed with dots and dashes — but on a different frequency. Before reaching this

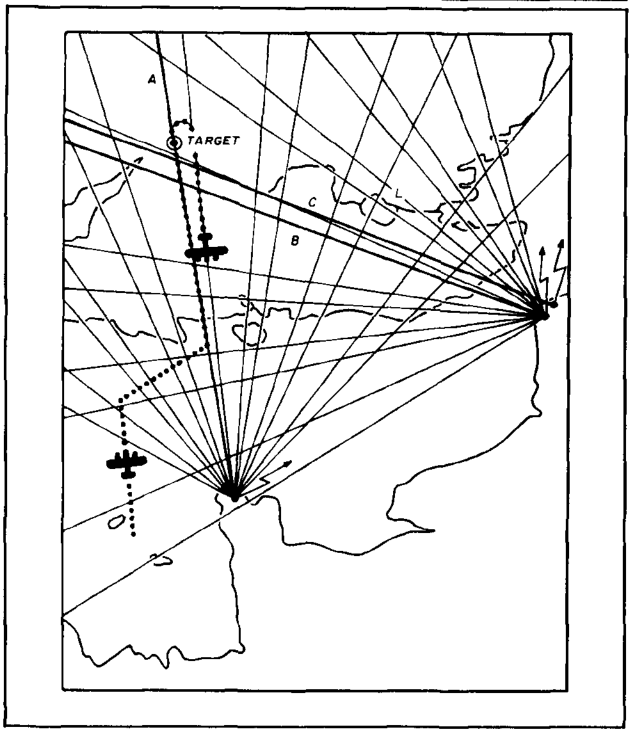
FIGURE 3



Official German layout of the X-Gerät system.

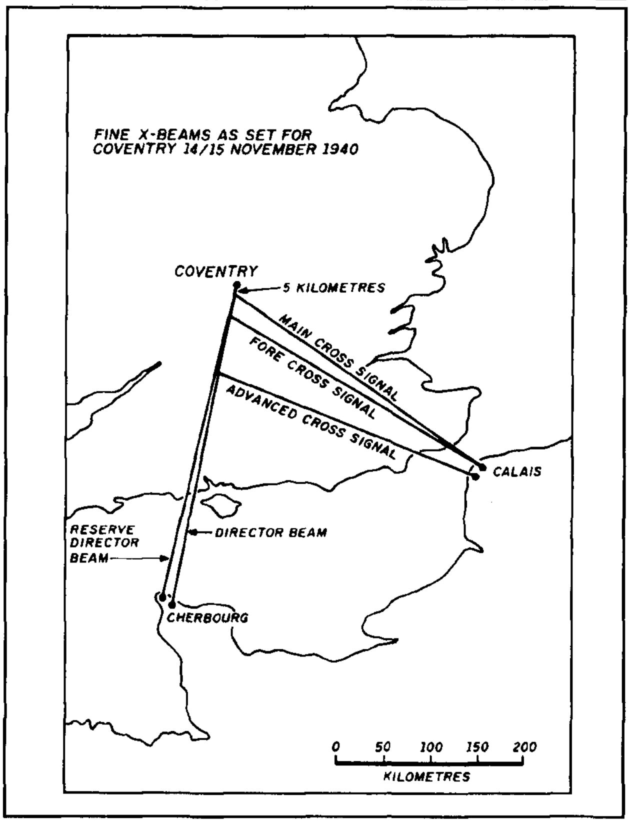
point, the bomber's radio operator would have consulted a table giving the characteristics of his particular type of

FIGURE 4



German layout of beams showing main beams and associated fans.

FIGURE 5



The X-Gerät system for Kampf-Gruppe 100.

machine and fed them into a combined calculator and stopwatch called the *X-Uhr*, or "X-Clock." This was an incredibly accurate mechanism designed at Rechlin by a Dr. Hepper. A small upper dial on the left-hand side showed how long the instrument had been running, while the lower dial was used for calculating the "flight-path ratios." Information about the aircraft's type, height, and speed was inserted to give a flight-path ratio of, say, 2.78:1 for 18 km or 3:1 for 6 km, according to circumstances.

On arriving in the dash zone of the advanced cross-beam, the operator would listen for the (very brief) continuous note produced by the merging of dots and dashes, and press the clock's top button. This started the green "minute" hand and the black sweep hand simultaneously and, according to the inserted data, the time taken for the bombs to drop was now fed in.

At the "fore-cross signal" a button on the left was pressed, whereupon the green and black hands stopped and the red "hour" hand started. When the third button at the main cross-beam was pressed, the red hand would stop at the same point as the previous ones and, if the correct data had been given, the bombs would be automatically released.

After tests by a research squadron, the system was finally installed in Ju 52s and He 111s of *Kampf-Gruppe 100* — a group led by an outstanding Luftwaffe officer, Major Viktor von Lossberg. Quarter-wave whips were mounted on top of the fuselage behind the cockpit and these, in conjunction with the whip antenna for RT operation which was situated farther back, gave rise to the nickname "Three-master."

The airborne equipment was installed in the radio operator's position, and repeaters for the course meters were fitted in the cockpit for the pilot's benefit. A motor generator fed from the aircraft's batteries (rotary converter) was placed at the bottom of the installation. Immediately above it were two audio units, to the left of which was the power distribution panel. The twin receivers for the director and cross-beams were above that and the Anna receiver was on the right.

Intelligence breakthrough

The phone shatterd Dr. R. V. Jones's sleep in the early hours of a morning during the first week of September 1940.

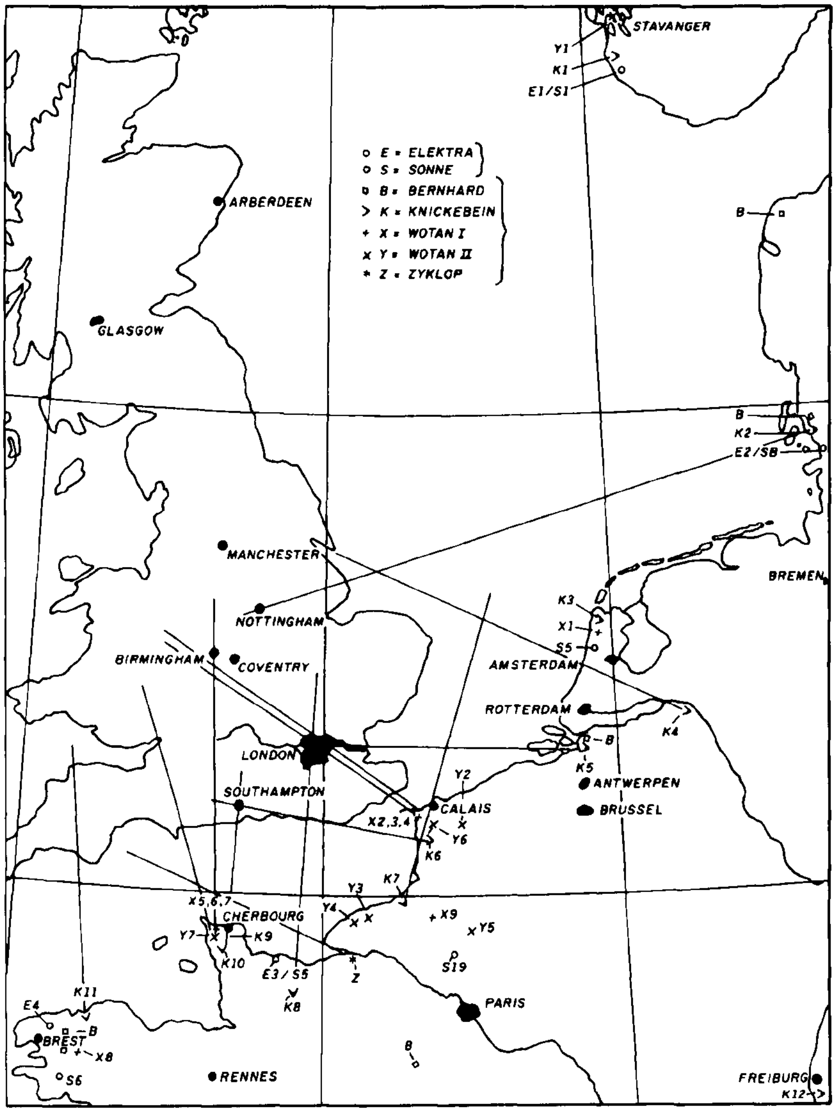
"We've got something new here! God knows what it is, but I'm sure it's something for you!"

The excited voice of Professor Frederick "Bimbo" Norman, a cryptographer at Bletchley Park, shook Jones into consciousness. They had broken some new Enigma traffic in which radio beams were mentioned, including the information that the beam width was 8 to 10 seconds of arc, or an angle of 1:20,000, suggesting that *the beam was no wider than about 20 meters at 320 km!*

Then came the electrifying word X-Gerät! Whatever X-Gerät was, it was being installed in aircraft of Kampf-Gruppe 100, one of the Luftwaffe's crack squadrons.

Jones hustled the intelligence services into greater activity. Across the Channel the Resistance organizations

FIGURE 6



Official German layout showing the disposition of all beam systems in use at that time.

pulled out all the stops, and British Signals Intelligence (including Voluntary Interceptors — a body of dedicated Radio Amateurs) doubled their efforts. Their activities prompted Jones to record his appreciation: *"Our community of Radio Amateurs in Britain was to prove an invaluable reserve, both in Signals Intelligence and Signals proper, as well as furnishing many of the staff for our rapidly increasing number of radar stations."*

It was that well-known Amateur of his day, Rowley Scott-Farnie, G5GI, then an officer in RAF Signals Intelligence and a close friend of Jones, who reported beam signals from the Calais and Cherbourg areas around 70 MHz. By September 24, six beam stations were identified: two northwest of Cherbourg, three near Calais, and the last near Brest. The Germans had code named them *Weser, Spree, Rhein, Elbe, Isar,* and *Oder.* Evidently Kampf-Gruppe 100 was working through a book of numbered targets, and by the time the stations were identified Jones had the actual directions for the beams — and even that the Germans had specified them to the nearest 5 seconds of arc, *an accuracy of about 10 meters at 320 km!* (See **Figure 7**).

But how could such an accuracy be possible on 70 MHz?

The "Anna" numbers

Further decoded German transmissions revealed the existence of coarse and fine beams, including a mention of centimeters. This latter, however, referred to the precision with which a monitoring vehicle had to be positioned to orientate the director beam. Frequent mention of something called "Anna" was made, usually associated with a num-

ber between 10 and 85, and often a multiple of 5. By October 17, Jones had collected 10, 15, 25, 30, 35, 44, 47, 55, 60, 75, and 85. Another set of numbers gave crystal frequencies (typically 8750 kHz, since 8750 kHz × 8 = 70 MHz) and he suspected that Anna referred to the dial on the aircraft receiver, if not the aircraft itself. Since one set of numbers ended in 0 or 5, and the other in 0 or 0.5, simple deduction showed that the Anna reading had to be divided by 10 and either added to, or subtracted from, a constant number.

Learning from the Enigma traffic that a certain Feldwebel Schumann at a beam station at den Helder had signed a return for 3 crystals for 69.5, 70, and 71.1 MHz and that his station was ordered to transmit on Anna numbers 30 and 35, it was clear that the constant had to be 66.5 if one-tenth of the Anna number had to be added, or 73 if it had to be subtracted. As he knew that crystals for 75 MHz existed, the second possibility could be dismissed; when he obtained further confirmation from the two crystals whose frequencies were not exact or half integers, the problem was solved. Other information that emerged from the Anna numbers was that both the coarse and fine beams lay between 66.5 and 75 MHz.

Measurement inaccuracy

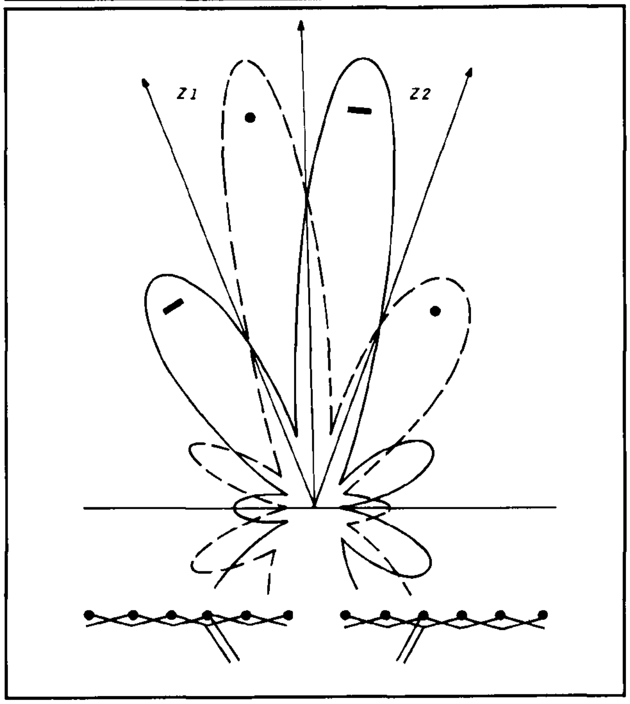
The immense value of Anna numbers was that if the transmitted orders to the beam stations could be decoded in time, he could then tell 80 Wing the frequencies to be jammed. Incredibly, his interpretation of the numbers was rejected because our monitoring services thought there were frequencies outside the range he had found. Dr. Jones's hackles rose — a posture they were seldom slow in assuming — and plain words were spoken. *"These, it transpired, were due to bad measurement of the frequencies of the German beams on the part of the countermeasures organization, a feature that was to plague us through the whole battle. The fault in this case probably lay not with the observers, but with the calibration of our receivers which were not up to the German standard of precision."* His findings were accepted.

Dr. Robert Cockburn of the Telecommunications Research Establishment, having successfully prescribed "Aspirins" for the Knickebein "Headaches," now developed "Bromides" for this new system which was code named "Ruffian." We now knew that the director beam was radiated from near Cherbourg and the cross-beams from the Calais area. As insurance against the failure of the main director beam (Weser), a reserve beam was provided by the adjacent station (Spree). The accuracy of the beams was so great that in calculating their paths it was necessary to take into account that the earth is not a sphere, but flattened towards the poles; this made a difference of 275 meters in where a beam from Cherbourg would cross London!

Countermeasures and counter arguments

Cockburn's jammers came into operation in October, but at this time Kampf-Gruppe 100 began to drop flares over its targets. This was hailed by some of Jones's antagonists as proof that the beams didn't work, or that the Germans were so unsure of them that they were using flares to find out where they were. However, Jones silenced these critics by pointing out that there was no evidence that Kampf-Gruppe 100 was upset by our countermeasures (which was true) and were not only using the system, but acting as pathfinders for other Luftwaffe groups.

FIGURE 7



Beam patterns ot mobile X-Gerät.

Yet other problems had to be overcome.

If the Enigma transmissions to the beam stations (usually sent out in the afternoon preceding a raid) could be broken in time, we would know where and when Kampf-Gruppe 100 was going to attack, and our fighters could be ready for them. Our jammers, too, could be set on the correct frequencies. For this to be possible the cryptographers at Bletchley Park strained all their resources — and it was a *magnificent* effort, for they achieved this incredible feat late in October. Dr. Jones was then able to tell Fighter Command the exact place of the attack, the time of the first bomb to within 10 minutes, the exact speed of the bombers, their line of approach to within 90 meters, and their height to within two or three hundred meters!

Yet our night fighters repeatedly failed to find the enemy. Jones wrote: *"I almost began to wonder whether the only use the Duty Air Commodore made of my telephone calls was to take a bet with the rest of the Command as to where the target would be for that night."* On top of this was the growing suspicion that our jamming was not working. Why not?

The answer soon came, but not before tragedy struck.

Moonlight Sonata

On November 10 Jones received an Enigma decrypt of a transmission to the beam stations which told them to prepare operations against target numbers 51, 52, and 53, giv-

ing the beam settings at the same time. It took only a few minutes to work out that 51 was Wolverhampton, 52 was Birmingham, and 53 was Coventry. Then another signal was passed to him which contained orders for a major operation under the code name *Moonlight Sonata*. Four target areas were mentioned but there was no indication of the *order* of the attacks. Frantic guesses were made by the Air Staff and the best they could come up with was that Moonlight Sonata might mean a target in southern England. Strangely, no attack had been made on Wolverhampton, and on November 14 everyone braced themselves for the coming night and whatever Moonlight Sonata might mean.

Tragically, it was one of those afternoons when Bletchley Park failed to break the Enigma signals in time, and 80 Wing asked Jones which frequencies they should set their jammers on, giving a list of frequencies as determined by our monitoring aircraft. *"I could see at once that the measurements must be wrong, in that they did not match up with the figures I knew from the Anna code. I therefore made a mental correction of the measurements as far as I could. For example, 68.6 should have been 68.5, if our receivers had been properly calibrated, or 70.9 should have been 71.0. But deciding what, for example, 66.8 meant was more of a lottery. The only other clue that I spotted was that there seemed to be a convention that the director beams would generally be on frequencies between 66.5 and 71.5 and the cross-beams between 71.5 and 75 MHz — the division being presumably due to operational convenience. Remembering that we needed to knock out the main and reserve director beams and at least one of the cross-beams, I then made my mental gamble and suggested a set of frequencies to Addison which he said he would adopt. All this took no more than five minutes on the telephone, but I was well aware that in these snap decisions I was probably gambling with hundreds of lives. Sobering though this thought was, the fact remained that someone had to do it, and I was easily in the best position."*

Then on the night of November 14th Coventry was attacked, with heavy civilian casualties. What had gone wrong? The next day the decoded Enigma signals to the beams stations arrived and Jones's wretchedness turned to bewilderment. He had guessed the frequencies correctly — so where was the failure?

Incompetence and carelessness

The failure arose originally from a silly interservice squabble which led on to a ghastly mistake. On November 6 one of Kampf-Gruppe 100's Heinkels became lost over southern England and ditched on Chesil Beach. The Army took over, secured a rope around the fuselage and set about salvaging it, when a naval inshore vessel arrived and demanded to know what the Army thought it was doing. As the aircraft was in the water, salvage was a Navy matter and taking the rope aboard they dragged the aircraft deeper into the sea, breaking the rope in the process. The X-Gerät equipment aboard, now heavy with silt and corrosion, was fortunately discovered and rushed to 80 Wing and then on to Farnborough for investigation.

On November 21 Jones, accompanied by Scott-Farnie and their assistants, went to see it for themsleves. They learned that Farnborough had examined the audio filter and found it set to 2000 Hz. But our jammers had been modulated at *1500 Hz*, which meant that while our carrier frequencies were correct the modulation tone had no effect on the beams.

"It was one of those instances, of which I have since found many, where enormous trouble is taken to get the difficult parts right and then a slip-up occurs because of lack of attention to a seemingly trivial detail. Of all the measurements in connection with the German beams, easily the simplest to determine was the modulation note, because this could be done at any time in comfort; and yet whoever had done it had either been tone deaf or completely careless, and no one had ever thought of checking his measurements. I was so indignant that I said whoever had made such a mistake ought to have been shot." It is hard to believe that the citizens of Coventry would have disagreed with this opinion.

Jones's anger was further increased by the fobbing-off he encountered. He was told that the modulation note was originally 1500 Hz but the Germans had changed their filters to avoid jamming. This ridiculous excuse was countered by Jones who pointed out that if that had been the case we would obviously have heard the change in note for ourselves. In any event he was able to prove that Kampf-Gruppe 100 had been using the same filters since the start of their operations.

On his insistence the jamming modulation frequency was changed and when the Germans later attacked Birmingham their bombs fell wide of the target, most of them outside the city. Gradually they came to realize we had broken X-Gerät and their confidence in the system diminished, and Britain which knew nothing about Dr. Jones and his scientific war went on with "business as usual."

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VERSATILE TRANSISTOR/DIODE TESTER

By Jim Owens, W5JQE, 20594 CR-150, Flint, Texas 75762 with G. D. Hanchett, W2YM

This simple and inexpensive transistor/diode tester shows shorts, opens, leakage, saturation and junction voltage, and relative gain or DC beta. It works on NPN and PNP bipolars, Darlington pairs, signal and power diodes, and FETs with junction or insulated gates in n- or p-channel, depletion or enhancement types. The tester also lets you solder and unsolder delicate FETs in chassis safely, using an ordinary ungrounded soldering iron. In the circuit diagram (shown in the off position) in **Figure 1** note that the RED (+), the RED (–), and the black base/gate (BG) leads are all connected together. You simply connect the micro clips to the transistor terminal wires in the following order: (–) to source, (+) to drain, and one or both of the (BG) clips to the gate terminal(s), and solder. Reverse the order when disconnecting the clip leads. Incidentally, all designators shown in parentheses — (+) and (–) and (BG), for example — conform to markings on the front panel and in the circuit diagram.

To understand how the tester works, set ganged switch S1-3 to the bipolar position (BP). Now trace the current path from the positive end of the AAA cells through CR1, CR2, R2, S1, R4, R5, the meter, R6, CR3, CR4, and S3 to the negative end of the AAA cells. The current drain of the R1 (BIAS) control on the batteries and the loading effect of the meter with its multipliers, along with R8 and R9, produce a voltage drop across the four diodes and the two 1000-ohm load resistors. This voltage drop lets you adjust R4 for 200 μA which registers full-scale deflection on the meter. The actual voltage between the RED (+) lead and the RED (–) lead will be approximately 2 volts. Note the (READ 2 VOLTS) label on the front panel of the tester.

The current drawn by the semiconductor device increases the voltage drop in the tester circuit, so the meter reads the voltage *across* the device instead of the current *through* it. This makes the tester versatile, easy to build, and reliable.

Testing procedures

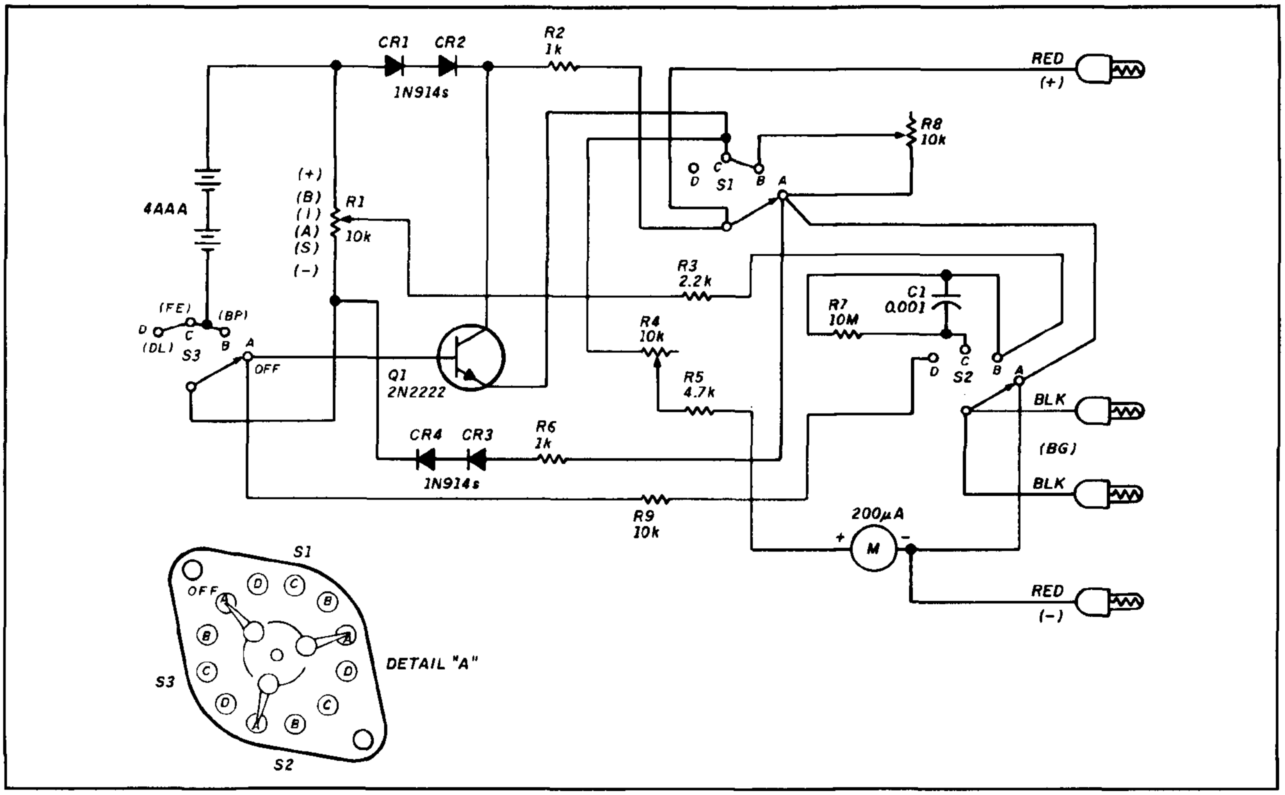
Try testing an NPN bipolar transistor. Set the S1-3 switch to (BP) and the (BIAS) control to its (–) end. Connect the test clips as follows: RED (–) to the emitter, RED (+) to the collector, and one of the (BG) clips to the base. The meter should read full scale, 2 volts, because the transistor is biased beyond cutoff. Now advance the (BIAS) control toward its (+) end. At some point the transistor will start to conduct; this will increase the voltage drop across R2 and R6, and lower the meter reading. At or before full drive, the meter should read 0.1 or 0.2 volt. It will be drawing about 2 mA and reading the saturation voltage of the transistor under the test conditions. This reading indicates a good transistor. A shorted transistor will read zero; an open transistor will read full scale. The (BIAS) control has no effect on either reading.

The test for a Darlington NPN is the same as for the regular bipolar, but there will be a difference in the meter reading. The Darlington saturates at about 0.5 volt. Transistors are somewhat bidirectional. They conduct and amplify in both directions, but have much lower gain in the wrong direction. So test any unknown unit in both directions.

> How do you tell an NPN from a PNP? Picture a bipolar transistor as two diodes in series. An NPN has its diodes back-to-back, arrows pointing outward. If you connect the (+) clip to the base and the (–) clip to the emitter or collector, there will be conduction with a drop in the meter reading. Conversely, a PNP has its diodes connected face-to-face, arrows pointing inward. So when you connect the (–) to the base and the (+) to the emitter or collector, there will be conductivity and a drop in the meter reading. However, if you connect the test clips to a PNP as an NPN, or vice versa, there will be little or no conduction and the meter will remain at or near full scale.

The test for a PNP bipolar is the same as for an NPN, except that the RED (+) clip goes to the emitter and the RED (–) clip to the collector. The rotation of the (BIAS) control is reversed.

FIGURE 1



Schematic diagram of the diode/transistor tester.

PARTS LIST

CAPACITORS

C1	*0.001 ceramic*

RESISTORS

R4,R8	*10-k potentiometer (RS 271-335)*
R2,R6	*1 k*
R3	*2.2 k*
R5	*4.7 k*
R7	*10 meg*
R9	*10 k*
R1	*10-k potentiometer (RS 271-1715)*

SEMICONDUCTORS

CR1-4	*1N914*
Q1	*2N2222 (RS 276-2009)*

MISCELLANEOUS

Meter	*(no. 20-907 Circuit Specialists)*
Case	*(RS 270-222)*
Knobs	*(RS 274-403)*
Test leads	*(RS 278-016 cut in half to provide four leads)*
S1-3	*four-position triple-gang switch (10YX034 Circuit Specialists)*

Possible parts suppliers
Circuit Specialists, Box 3047, Scottsdale, Arizona 85257
Mouser Electronics, Box 699, Mansfield, Texas 76065
DC Electronics, Box 3202, Scottsdale, Arizona 85257
Madison Electronic Supply, 3621 Fannin, Houston, Texas 77004

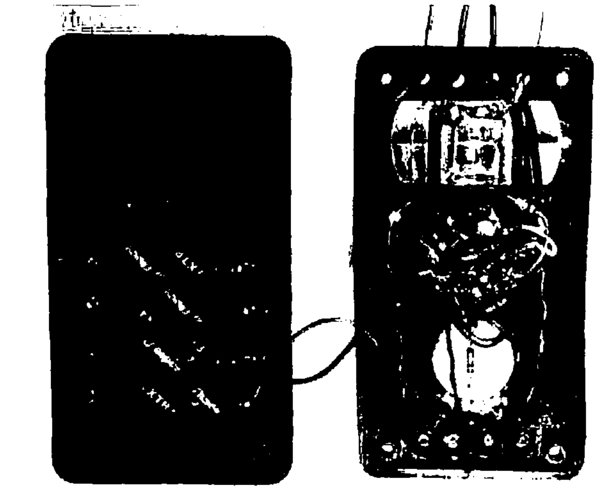
Test all bipolar transistors for leakage in the same manner. Remove the (BG) clip from the base following the saturation test, allowing the unit to self-bias beyond cutoff. If there's no collector-to-base leakage, the meter immediately rises to full scale. You can expect germanium units to show some leakage — the meter won't rise all the way to full scale. However, these units may still operate satisfactorily in circuits designed for them.

Selecting matched pairs is easy. Test the first one with the (BIAS) control set for a reading a little above the saturation voltage. Then try others; don't move the (BIAS) control. Choose the two with the nearest to identical readings.

Testing J-FETs and MOSFETs

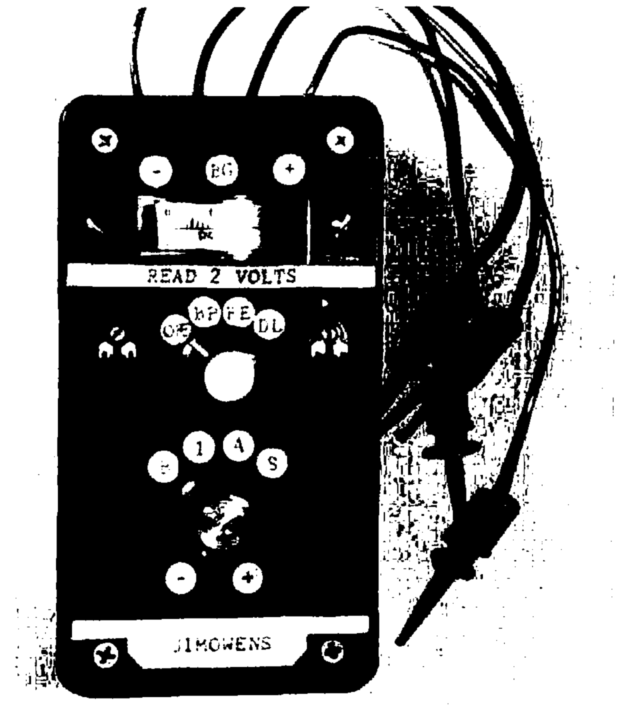
Test field-effect transistors as you would bipolars, but place the S1-3 switch in the (FE) position. This puts a 10-meg resistor in series with the gate. Try a junction gate for your first test. Connect the RED (–) to source, the RED (+) to drain, and one of the (BG) leads to the gate. Rotate the (BIAS) control from cutoff to saturation. As with a bipolar, this occurs at about 0.1 or 0.2 volt. However, if you drive the gate into conduction, the voltage at the source will drop to near zero. To test for leakage, readjust the (BIAS) control for a mid-scale reading and then switch from (FE) to (BP). There will be no change in the reading if there's no leakage. Next, test a dual gate FET like the 40673. Connect the RED (–) clip to the source substrate terminal, the RED (+) clip to the drain terminal, and the (BG) clips to the gate terminals. It will saturate at the same level as the junction FET. Use the same test for leakage. Follow the same procedure for testing a single gate, but expect the saturation voltage to be double that of the dual gate.

PHOTO A



Inside view of the tester.

PHOTO B



Completed tester, front panel view.

Diodes and rectifiers

Semiconductor manufacturers test diodes and rectifiers for forward bias voltage drop (a measure of junction voltage). In the shop or shack, junction voltage is the best indicator of the character of any diode. This measurement is easy to make. Put switch S1-3 in the (BP) position, then connect (+) to anode and (–) to cathode. A zero reading indicates a short; a full-

scale reading indicates an open. Silicons read approximately 0.6 volt and germaniums read approximately 0.3 volt. Find matched pairs by selecting units with near identical junction voltage. Junction voltage is a more reliable figure of merit than the common ohmmeter resistance reading, in which one scale belies another.

Semiconductor manufacturers specify reverse bias diode leakage in microamperes. Hams talk about it in terms of kilohms or megohms, because we have only our ohmmeters to assess it. Actually, the resistance measurements correlate quite well if they are made above the voltage or current knee. To perform the test, set switch S1-3 in the (DL) position, connect the (+) clip to the cathode, and one of the (BG) leads to the anode. Germanium diodes have reverse bias leakage resistances ranging from thousands to millions of ohms. The usual range for rejection or acceptance lies between these extremes. This calls for a nonlinear meter scale, expanded on the high end and compressed on the low end, with a midpoint of about 500 kilohms. Exact readings aren't important; a point-to-point table will do. (You can glue it to one side of the instrument case.) The following is a tabulation of scale readings versus resistance values which I made for the model.

200 = zero ohms = full scale
150 = 180 k = 3/4 scale
100 = 560 k = 1/2 scale
50 = 1 meg = 1/4 scale
0.05 = 20 meg ≃ no movement

The high resistance point at half division is useful mostly for checking silicon diodes. Silicon diodes are rated at near-infinite resistance; any unit that barely moves the meter is technically a reject. Compare that with a germanium 1N34 which is acceptable with a leakage resistance as low as 100,000 ohms.

In-circuit testing

It is important that an in-circuit tester be nondestructive. With this in mind, I like to use out-of-circuit procedures in an orderly system as follows:

- Connect the transistor as you would out of circuit.
- If the transistor tests OK, move on.
- If the transistor tests NG, unsolder the base or gate and repeat the test.
- If the transistor tests OK now, move on. If not, unsolder the collector or drain, and make one final test. This one is conclusive.
- If you are testing an FET, use the soldering/desoldering technique described at the start of this article.

Construction

All wiring is point-to-point. **Figure 1** is drawn to be a mechanical as well as an electrical diagram. Note that the (OFF) post on S3 is a tie point for Q1's base and R9. Q1 is an emitter-follower current amplifier which drives the meter directly. R9 attenuates the drive to Q1 so that a short between RED (+) and (BG) makes the meter read full scale.

I made the round panel markers from a self-stick file folder label. You can also use ordinary typing paper with a speck of glue. Mark them with a typewriter or fine-tip pen. Use a 1/4-inch punch to extract the markers from the label. (Rub-on lettering is another possibility. Ed.)

R8 is used to load the supply to get 2 volts between (+) and (−). R4 sets the meter to read full scale. There is some interaction between them. **Figure 1** and Detail A show switches S1-3 going counter-clockwise from (OFF), as seen from the rear of the panel while you're doing the wiring. From the front of the panel, the rotation is clockwise. Photos A and B show an inside view and the completed tester.

A HIGH PERFORMANCE DUOBAND YAGI
FOR 15 AND 20 METERS

Two PV4s on a single boom

By David J. Rodman, M.D., KN2M, 368 Hedstrom Drive, Buffalo, New York 14226

Multiband antenna systems with traps, loading coils, or similar devices are common in Amateur Radio. These antennas have many distinct advantages — they can be purchased easily, are constructed simply with manufacturers' kits, are generally fed directly with a single coax line, and give modest performance. Monoband antennas aren't as popular — except within the realm of antenna afficionados, like contest enthusiasts. The superior gain and efficiency advantages of monoband antennas are often outweighed by the antennas' large size, cost, and complexity on a single tower.

I came up with this antenna project when the bands were in the doldrums of the sunspot cycle; that's why it doesn't address a triband system that would normally include the 10-meter band. I made an attempt at a compromise based on the needs of Amateurs who require multiband systems for the most popular HF bands, with the efficiency that approaches separate monoband antennas.

Theory

Wilson Electronics Corporation was the most recent manufacturer to address the idea of a duoband antenna system. Such antennas were adequate performers on the lower frequency; however, when used with the higher frequency, operators found not only that the gain was less than advertised, but the front-to-back ratio was dismal. While the use of two harmonically related or unrelated frequencies on the same boom has been addressed, don't assume that harmonically unrelated antennas in this configuration are devoid of element interaction.[1] In fact, just the opposite is true. Positioning harmonically related or unrelated elements in close proximity to any antenna tends to invite electrostatic shielding in some configurations. This shielding affects the higher frequency antenna more than its lower frequency counterpart because of the size of the elements. The effects of this interaction are most pronounced when antennas share the same boom. Electrostatic shielding also alters antenna performance when separate antennas are spaced inadequately.

Duoband antennas show degradation of front-to-back ratios on all frequencies, and forward gain reduction on the higher frequency antenna, as a result of electrostatic shielding. You'll need to anticipate this problem before you start to build if you want to improve your antenna's performance. Empirical estimations of element placement appear to be no better than chance in designing such antennas, and yield equally poor performance. To ease this burden for Yagi design, use computer modeling programs to simulate antenna performance before actual construction. These programs let you make accurate and precise iterations of design parameters in minutes.

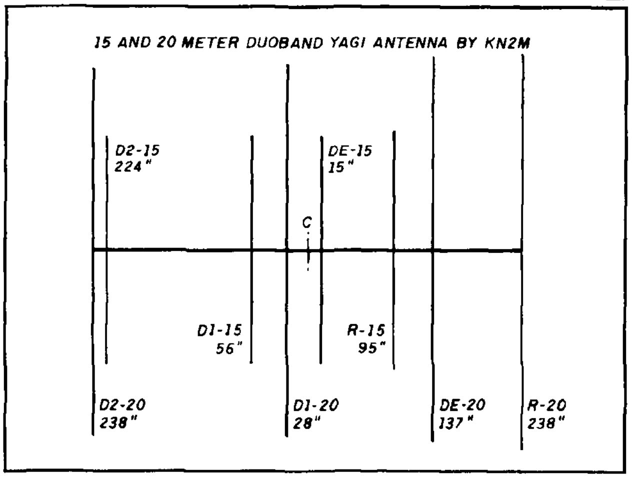
Design approach

I used MININEC to develop my antenna. MININEC lets you alter element size and spacing until both forward gain and front-to-back ratios are maximized at the desired operating frequency and height above ground. Actual antenna testing with distant observers showed that measured performance can even surpass computer predictions.

Before I discuss the optimization technique, I'd like to make several points concerning computer modeling. First, actual MININEC calculations are dependent upon the CPU type, clock speed, and the presence of a mathematical coprocessor. Use the fastest system available to speed your calculations. Second, it's extremely difficult to model commercial multiband trap Yagi antenna designs. You need to specify all complex reactance values along with their locations in three-dimensional space precisely, before even attempting this. Don't expect to redesign trap antennas easily with such software. Finally, the calculations performed for my antenna required exhaustive changes in element position and length before I made my final design selection. Conceptually, it's similar to tuning a circuit with eight unknowns. The system performs as described for the dimensions and element taper specified. Small deviations from these specifications won't necessarily produce the same results. If you want to alter these values, I suggest you use computer modeling to make your changes.

The method required to maximize the performance of this

FIGURE 1



Element name code and distance from boom center.

or any similar project is as follows. First, start with a design showing element size, location, and diameter. Translate this data into a simple mock-up of the antenna (ignoring element taper) modeled in free space. With MININEC, calculations in free space are much faster than those performed over real ground. When you've produced a suitable design, model the antenna over real ground at the desired height. Once your design proves satisfactory, make a real model of the antenna with the actual taper schedule in free space. I used a BASIC program written by Bill Myers, K1GQ, called TAPER.[2] Finally, model the actual antenna over real ground. At any point in the analysis, you can vary element location to maximize the front-to-back ratio and minimize loss in forward gain. These values are generally inversely related, and give many opportunities for producing either a suitable design or one that becomes increasingly undesirable. Throughout your calculations, remember to accommodate maximum gain and front-to-back ratios at the design frequency.

Results

The antenna design is shown in **Figure 1**. This antenna system is based on the PV4 antenna designed originally by the late Jim Lawson, W2PV. The antenna was only recently introduced to the general Amateur population.[2] I read several sources before building the antenna that provided excellent background on construction.[1] The characteristics of this array are similar to previous descriptions in that gain is fairly constant over each band, but the front-to-back ratio peaks in a narrower frequency range.

Essentially, I've mounted two of these antennas on the same boom and redesigned them carefully to maximize antenna performance. Lawson was the first to note that gain is dependent on boom length. He also observed that front-to-back ratios are maximum at odd multiples of quarter-wave boom lengths.[3] Here, in contrast to those findings, gain and especially the front-to-back ratio of the higher frequency antenna are inevitably decreased by the electrostatic shielding of two antennas on the same long boom. The only way to maximize the front-to-back ratios of the two antennas is to perform repeated calculations with MININEC. Despite this technique, the gain on 15 meters is less than on 20 meters for the same electrical boom length. A rule of thumb when designing multiband antennas like the one described here is that the gain of the higher frequency antenna will approximate a three-element array of lesser boom length. A comparison of this data is shown in **Table 1**. If you can accept the fact that the 15-meter portion behaves more like a three-element antenna on a 0.3-wavelength boom, then this is by all accounts an excellent system. You now have a multiband Yagi without traps, but with maximum gain and front-to-back ratio at the design frequency. The system does require separate feedlines and matching devices for each band.

As you'll note in **Table 2**, the design uses relatively large element diameters. I selected aluminum sizes in an attempt to keep construction as rugged as possible. Moreover, with a large element diameter, the SWR bandwidth is increased by maintaining relatively low element Q. You can match your antenna with a gamma match or a beta device, whichever you like better. Note that the driven element length here has been shortened somewhat to produce the capacitive reactance necessary for the gamma match actually used in construction.

TABLE 1

Duoband antenna electrical characteristics for 14.175 and 21.2 MHz.

	Forward gain	Calculated F/B	Measured F/B	Input Z
20 meters	10.0 dB	25.4 dB	40 dB	19.4-j22.8
15 meters	7.9 dB	25.1 dB	35 dB	14.9-j20.1

TABLE 2

Duoband antenna element half-length data for 14.175 and 21.2 MHz.

Location	Length 15 inches	OD 15 inches	Length 20 inches	OD 20 inches	Material
Segment 1	72	1.125	72	1.125	6063-T6 0.049 wall
Segment 2	End piece varies	1.0	68	1.0	6063-T6 0.049 wall
Segment 3	none	none	End piece varies	0.875	6063-T6 0.049 wall

TABLE 3

Duoband antenna element end piece length data for 14.175 and 21.2 MHz.

Element	Length 15 inches	Length 20 inches	Distance to boom center inches	
Reflector	67.0	74.4	15-95	20-238
Driven element	59.0	58.2	15-15	20-137
Director no. 1	57.6	55.9	15-56	20-28
Director no. 2	55.0	49.9	15-224	20-238

Construction

Before assembling this antenna, remember to follow and reproduce exactly the dimensions specified by computer modeling (Table 3). If you don't you will get a less than optimal result, first noted in decreased front-to-back ratios.

There are advantages to using this particular configuration with a 40-foot boom. First, this is an excellent length for the 20-meter band, giving 10-dBi forward gain. Shortening the boom sacrifices gain on the most popular HF band. Second, the boom material (3-inch OD 0.065-inch wall aluminum tubing) is available in 20-foot lengths. The boom halves can be joined with a 3-foot piece of larger wall 2.875-inch OD tubing.

Be sure to place furniture foot caps on the ends of all elements during construction. This eliminates the risk of damage during ice storms. I also suggest using conductive grease at all element telescoping positions. Use simple hose clamps to secure each telescoping joint. To help retard weather corrosion, coat all hardware surfaces during construction with a clear aerosol varnish designed for outside use.

As I mentioned before, there are mechanical disadvantages when using the PV4 antenna. Because you use odd element spacing, the driven element location and matching device are at some distance from the mast. This antenna also needs a substantial boom brace because of the number and spacing of elements, and the fact that PV4 antennas tend to have a center of gravity away from the boom center. You'll note that the 15-meter portion of this antenna has been moved towards the director end of the boom. This makes it possible to adjust the matching device for that band while the antenna is on the tower. The array also has less tendency to be reflector heavy.

Many of you may shy away from any antenna project that requires construction and adjustment of a matching device. Because this antenna requires some reorientation during adjustment of the match for 20 meters, I'd like to make some points that should simplify these tasks. First, a calibrated noise bridge is invaluable for determining feedpoint resistance and reactance values. Second, if you use an odd multiple half-wavelength line for these measurements, you can even make them in the shack. Third, the actual feedpoint impedance may be measured more conveniently and with greater safety at a height lower on the tower, as it may be necessary to tilt the array upwards to reach and adjust the match.

Conclusion

The antenna design I've presented shows how current technology allows optimization of Yagi performance beyond previous methods. Computer analysis now replaces most antenna range testing. I've used my antenna at heights of up to 1.4 to 2 wavelengths above the ground. It performed well when contacting DX stations. The front-to-back ratios, both predicted and measured, are extremely favorable when compared with commercial antennas.

This antenna, like any multiband, has limitations. However, should you build one of these, you should notice definite improvements in band-centered gain and front-to-back ratios over multiband commercial antennas. Using a duoband antenna like this lor the new 17 and 12-meter bands should give satisfying results with a single array. hr

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CQ WW DX
PHONE CONTEST

The story of 1988's record-breaking effort

By Mark Allen, WJ7X, National Service Manager, Icom America, Inc.

I was taking a late night flight home from the Dayton Hamvention™ in 1988. As I settled into my seat, I saw the face of an old friend, Danny Eskenazi, K7SS, in a distant part of the sparsely occupied cabin. When I went over to say hello, I found Danny sitting with John Kiesel, KE7V.

The conversation drifted from topic to topic during the long flight, until the subject of a DXpedition came up. Danny's eyes beamed as he asked if I might be interested in lending technical support to a possible DXpedition to Aruba. Carl Cook, AI6V, had talked with Dan and several other operators about putting the DXpedition together in an attempt to win the 1988 CQ Worldwide DX Phone Contest.

The idea appealed to me greatly; however, my skills as a contest operator were minimal. I thought the DXpedition might be a good vehicle to get back into the contesting scene.

The remainder of the flight was occupied with talk about the most efficient way to beat our competition from both technical and operating standpoints. As I listened, I realized that I had fallen years behind the other operators in contesting.

About the time my enthusiam reached its peak, I was informed that Carl was going to run the operation on a "by invitation only" basis. Getting an invitation was going to be difficult, unless I had something specific to contribute. My contribution would definitely have to be my technical skills. As we left the plane in Seattle, Dan assured me that he would see what he could do.

Carl called a few days later. He said there was a rumor circulating that I was interested in getting involved in his planned Aruba DXpedition. Without the slightest hesitation, I told him "absolutely."

After a brief rundown of my technical background, Carl decided that it would be a good idea to have me along. Although I didn't realize it, my 20-year ham radio career was about to change dramatically.

Carl immediately put me to work on a series of challenging technical questions. He asked if I realized the range of the problems caused when six stations were operating simultaneously in a confined geographic area. I have had quite a bit of experience in this type of situation and an extensive career in the broadcast industry, so I was very familiar with the problems. However, I had never encountered anything of this magnitude. Carl decided that because I had experience in the Caribbean and Bahamas, I would also be a good person to coordinate our equipment shipments from the United States to Aruba.

Over the next several months, the scope of the project changed considerably. Carl recruited Evelyn Garrison, WS7A, to develop the concept of a ***TEAM ICOM***. ICOM would pro-

vide equipment for the effort and make transportation arrangements. In a meeting held shortly thereafter, Ron Rueter, NV6Z; Daniel Handa, W7WA; John Kiesel, KE7V; Dan Eskenazi, K7SS; and I had our first discussions about the exact types of equipment and station layouts we were going to use.

Although I didn't know it at the time, Murphy's Law was about to complicate our plans.

Our equipment list included: two IC-781s, three IC-761s, two IC-751As, seven IC-735s, four IC-12AT handi-talkies, power supplies, microphones, and various other accessories. We spent the next month drawing layout diagrams for each station, required antenna configurations, bandpass and band cutoff filters, and calculating the amount of coax cable and rope we'd need. Carl was a great help to us since he had coordinated such operations before and was familiar with the field problems involved in erecting massive numbers of antennas. At the last minute, Dick Ehrhorn, W4ETO, of ETO Alpha Amplifiers, offered a loan of Alpha 86 amplifiers. The group was very happy about this addition; it would add another couple of dB to our signal.

The logistics

By July 1, 1988, things were beginning to happen. Hundreds of hours had been invested in the project for planning, drawing, replanning, and computer analysis. It was at this time that I had my first contact with Tom Schiller, N6BT, whose area of expertise is antennas. His prowess at optimizing antennas absolutely amazed me! Tom and I had several discussions, and he ran a computer optimizing program to find the best antenna configurations.

Finally, the time came to find a place to collect all our equipment. We had amplifiers, radios, tower sections, cable, rope, and antennas. John Lopez of International Radio Systems in Miami graciously loaned us a warehouse facility. During July and August quite a bit of material arrived at John's warehouse.

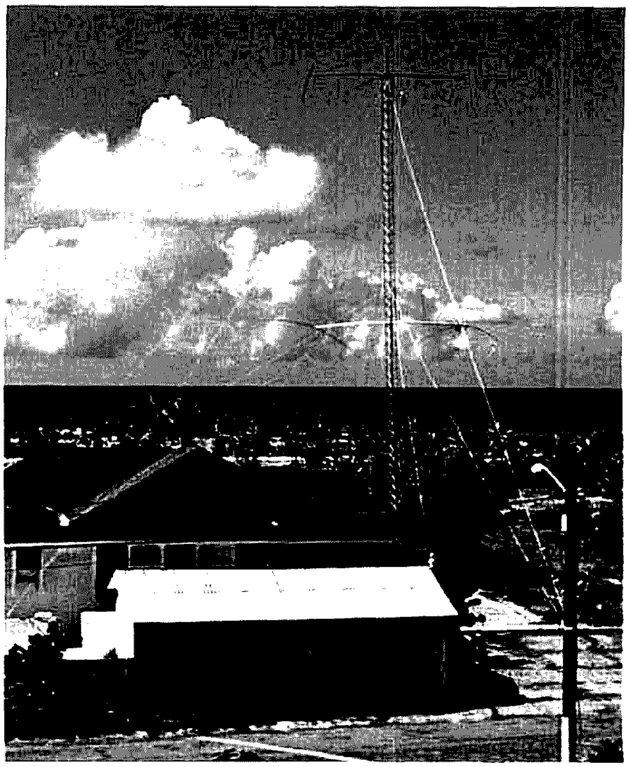
In the meantime, the activity at ICOM continued at a frantic pace. All the equipment being sent to Aruba was new. First it was functionally checked for "infant" failure problems. ICOM's HF technician Russell Dudley, KW5O, coodinated this effort. Every conceivable parameter was checked on the 781s, 761s, 751As, and 735s. I began assembling spare parts kits, which included service manuals, owner's manuals, and parts that wouldn't be available in the field.

Although I didn't know it at the time, Murphy's Law was about to complicate our plans.

I had contacted a freight-forwarding service in Miami and had been assured that equipment transportation to and from Aruba would be no problem. Their planes, they said, flew to the island on a daily basis taking supplies to the hotels and casinos. It was here that I made my first mistake. Assuming that anyone who transported casino and hotel supplies should surely be well connected, I didn't do any serious checking. Boy, was I ever wrong!

Around the middle of August, I called Dick Ehrhorn, W4ETO. He informed me that all the amplifiers had been checked, rechecked, and shipped to our collection point in Miami. I also confirmed that all the tower materials, antennas, rope, and coax cable had also been shipped. ICOM shipped their equipment, and the whole project was in the hands of the trucking companies and UPS.

By September 1st, all the equipment had reached Miami



and was being prepared for shipment to Aruba. There was not the slightest hint of trouble.

After extensive consultations with the Miami freight company, it was determined that the equipment needed to arrive by October 15th; the nominal shipping time to the island of Aruba was three or four days. We were told: "No problem." Murphy laughed at our ignorance.

A small setback

On Monday October 17th, I received a panicked call from Carl. He was in Aruba, but there was no equipment waiting.

The first call to the freight company indicated that the equipment had been picked up, shipped, and was in Aruba. Carl spent the remainder of the 17th and most of the 18th trying to locate it. Finally, after scouring customs, the air freight office, and the island, he determined that the equipment was just not there. Another call was made to the freight company. They were absolutely sure the equipment had been shipped and had flight and waybill numbers to prove it. Carl spent most of the 19th and 20th of October calling from Aruba, trying to locate the shipment.

Meanwhile, Hurricane Gilbert was lashing the islands of Bonnair and Curaco, and there were heavy rains and stray winds on Aruba. Time was rapidly running out. The entire crew was due on Monday the 24th to begin assembling the station and raising towers and antennas. Unfortunately, there was nothing for them to raise.

Late on Thursday October 20th, Carl determined that the freight had been shipped on the 19th. However, it had been sent to Curaco instead of Aruba. It seemed that the air-freight company was temporarily banned from landing in Aruba.

On Friday the 21st, we discovered that the freight agent in Curaco handling our shipment was an Amateur operator. Carl pleaded with him and explained the problems we were having. Magically, the brotherhood of Amateur Radio came

together. The shipment began arriving on the 22nd. The majority of it was in place by the 24th. Unfortunately, we discovered that we were still missing all of the antennas. We began working our way backwards and finally discovered that the antennas inadvertently had not been shipped from Miami. We made a hasty call to American Airlines air freight and they arrived on the 26th. We went to work building antennas the instant Carl drove in from the airport. Although we had built the towers on the 25th and 26th, we didn't actually get to put up the antennas until late Wednesday. Antenna erection continued throughout the day on Thursday and finished the morning of Friday the 28th, with the contest a mere twelve hours away! I left Seattle on the 24th, planning to land in Aruba later that night.

When I arrived, I found that the shipment had finally made it. Most of the equipment had been removed from its shipping containers and checked. Aside from a minor ding to an amplifier, the equipment had reached its destination in good condition — despite its detour!

The work proceeds

Meanwhile, all our technical plans were falling into place. There were two houses a short distance apart. We decided that the 10, 15, and 20-meter activities would be headquartered at one house. The Forty, 80, and 160 meters would be

at the other, which had a large open field that we would use for our Beverage antennas.

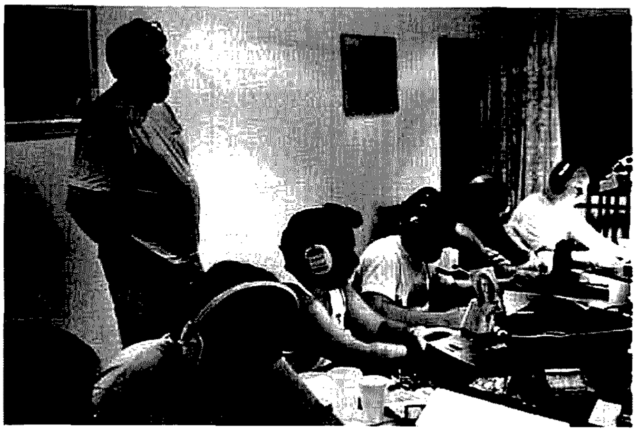
Two 781s were assigned to the 40 and 80-meter positions; the 160-meter position had one 751A, and three 761s covered 10, 15, and 20 meters. The 735s were used parallel to each position for spotting radios. They were connected via a relay network so the spotter operator could take control of the amplifier and antenna to grab a rare contact.

The antenna system generally consisted of four-over-four stacks on 10, 15, and 20 meters. The lower antennas were fixed and connected via a phasing harness to the upper, rotatable antenna. Stacked two-element beams were used in the same configuration on 40 meters. The antennas for 80 and 160 meters were pure magic! Wally Eckles, W8LRL, noted low-band DXer, appeared on Wednesday with the supplies to build the 80 and 160-meter antennas.

Wally proceeded to construct one of the largest low-band Beverage arrays I had ever seen! The transmitting antennas were an array of long wires, slopers, and a vertical made out of pipe borrowed from a local refinery. Stringing out the wires for the Beverage was an interesting experience. We traipsed through coral fields, slightly overgrown with underbrush and overrun with small iguanas. The ground around us moved continuously, as the lizards scurried about.

After all the antennas were up, everyone began making cables. There were hundreds of PL 259s to be installed on various types of coax cable. Our low-frequency antenna construction had fallen behind schedule. Consequently, the 160 station didn't get on the air until several hours into the contest. Station after station was falling together when, all of a sudden, Murphy struck again!

What we thought was going to be a simple licensing procedure for our operations became a total nightmare. Problems with the local telecommunications agency necessitated going all the way to the Minister of Telecommunications. The Minister, a most gracious gentleman, expedited our paperwork at an unbelievable pace. He assigned his assistant to take care of our needs, and though we had gotten off to a slightly rocky start with the local government, our P4Ø licenses came through at the last possible minute.



After all the months of planning, hundreds and hundreds of hours of work, and monumental expense, the contest was on!

We spent Friday the 28th cautiously tuning up amplifiers and radios. Amazingly enough, everything worked! The antennas performed as well as (and in some cases, better) than we expected. We keyed up transmitters at each location, to check our power requirements and to see if the AC wiring in the residences would stand the load. We found no problems with the AC power in either the HF or the LF house.

As Friday continued, everyone performed extensive equipment checks and rechecks. I found myself running from pro-

jecl to project, taking care of problems with flip switches, headset wiring, digital voice keyers, and every other aspect of the operation. Since this was a group of the world's finest operators, I was hardly about to question why each one of them needed a different kind of headset. There were as many different headsets, microphones, and keyer arrangements as there were operators. Contest time was now just six hours away. I was still frantically putting PL-259s on coax for short jumpers, rechecking the tuning on amplifiers and interfacing headsets.

We began our final on-the-air testing late in the afternoon of October 28th around 2200 Z. With one exception, all was operating well. Our 160 antenna was still under construction. W8LRL was hard at work building an antenna tuner to replace one that accidently got left behind.

The contest

By now, blood pressure readings for the first shift of operators were far above safe levels. Everyone and everything was ready to go. It was hard to believe the contest was finally beginning. After all the months of planning, hundreds and hundreds of hours of work, and monumental expense, the contest was on!

Approximately two hours into the contest, the 160-meter antenna problems were resolved, and the 160 station got on the air. Dick, W4ETO, and I continually monitored the heartbeat of the system. Dick kept an eye on the Ehrhorn amplifiers, and I watched all the ICOM equipment and peripheral devices.

Dick and I crossed paths when the contest was about six hours along. We discovered, to our excitement, that neither of us was having any equipment problems. We were amazed that everything was working; all the equipment was talking, but not to each other! We attributed the success to good equipment and excellent planning.

I finally closed my eyes around 3:00 a.m. Saturday morning, only to be awakened at 4:30 a.m. by Tom, N6BT, the on-the-air coordinating officer. He told me that the 15-meter station was down and nobody could figure out what was wrong with it. Ron Rueter, NV6Z, met me at the 15-meter position. It took two and a half minutes of troubleshooting to determine that a coax line was open. We replaced it quickly with a spare line, and 15 was back on the air. The total downtime was about six minutes. This was the only failure of any item during the contest.

By noon Sunday we hoped that the equipment would continue to operate without failure. Tom was passing out some promising information. Scores were stacking up impressively; they were even higher than we had expected. As each hour passed, the chances of Murphy striking again were reduced by several orders of magnitude. It was apparent that we were closing in on a new world's record. We had had a small rain shower and I nervously watched Bird watt meters for reflected power. I was sure that many of the outside connections were untaped — although we had tried to tape each of them.

I d been so busy keeping an eye on all the equipment that I hadn't noticed that the support crew had put champagne on ice. This was a good indication they knew something that I didn't. I made a quick check with N6BT; our score was running well above what we expected.

Finally, it was over; it was hard to believe. We had run the whole weekend without any equipment failure. There was much nervous talk about the exact status of our final score and our standing in the contest.

By Tuesday many of the operators had returned home; they had all been on tight vacation schedules. This left about five of us to disassemble and pack. Before we got started, we got word that ICOM was willing to sponsor the group for the CW contest that was coming in several weeks. With that news in mind, we took down the low-band station equipment and all but two operating stations of the high-band station and put them in storage.

All too soon it was time to leave and head back home. Eight months of planning and hundreds of hours of effort had paid off. As I stepped onto the plane to leave P4Ø land, I realized that I had been part of a world-champion DX team — a claim very few operators can make!

The final score, after all was checked and duped, was 54,864,040 points. This should surpass the old world's record by 12,906,796!

I realized that I had been part of a world-champion DX team — a claim very few operators can make!

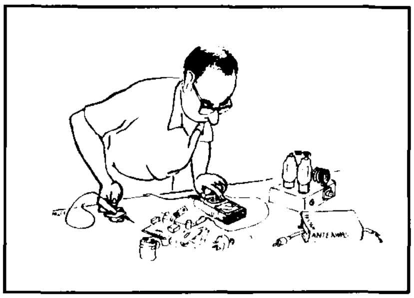
A successful contest formula

Frequently, I'm asked what single element played the most important part in the success of the DXpedition. The answer is planning and teamwork. The effort could not have been successful without extensive planning. Also, if all the members of the team had not worked so well together, the venture would have failed.

I'm also asked how much equipment I took to do the installation and maintain the station on the air during the contest. I took my old faithful Bird watt meter with a full selection of elements, a set of hand tools, large and small soldering irons, a logic analyzer and a multimeter. I'd advise future DXpedition organizers to have operators submit itemized lists of the equipment they bring, in addition to marking each item with their name or callsign. Each of our operators was asked to bring such things as coax relays, keyers, headphones, and individual operating accessories. Consequently, we had quite a problem making sure everyone got back what they brought as we disassembled the station.

The attitude of our entire group during this DXpedition is best summed up by the saying on the license plates on the small, friendly island of Aruba. It says, "One happy island." We maintained our sense of humor and optimism during the long hours of planning, setup, and the contest itself. And the results paid off.

Ham Radio Techniques



Bill Orr, W6SAI

THE GAMMA MATCH: AN UPDATE

When the 88 to 108-MHz FM broadcast band was authorized shortly after World War II, a VHF transmitting antenna using an off-center feed system was introduced. Adapted for Amateur use, the system was termed the "gamma match" and was featured in *QST*, September 1949. The builder, H. Washburn, W3MTE, remarked that the device worked well, permitting him to achieve an SWR value as low as 1.75:1. His arrangement is shown in **Figure 1**.

Several other antenna experimenters and I worked with the W3MTE gamma match. We soon determined that to lower the SWR appreciably below 2:1 a variable capacitor had to be placed in series with the gamma rod (see **Figure 2**).

Little information was available on optimum rod-to-antenna spacing, rod length, or rod diameter. It was strictly a cut-and-try situation. Some Amateurs had good luck with the device; others couldn't get it to work. The gamma match soon got the reputation as a tricky device that was hard to adjust. In time, it became apparent that the gamma rod had to be small in diameter compared with the driven element, and that the spacing of the gamma rod to the element had to be quite large compared with rod diameter, in order to make the system work properly.

Some attempts were made to analyze the gamma match using transmission line equations. But it wasn't until Harold Tolles, W7ITB, analyzed the device[1] that a computer program was derived that would predict gamma dimensions accurately for a particular antenna.[2]

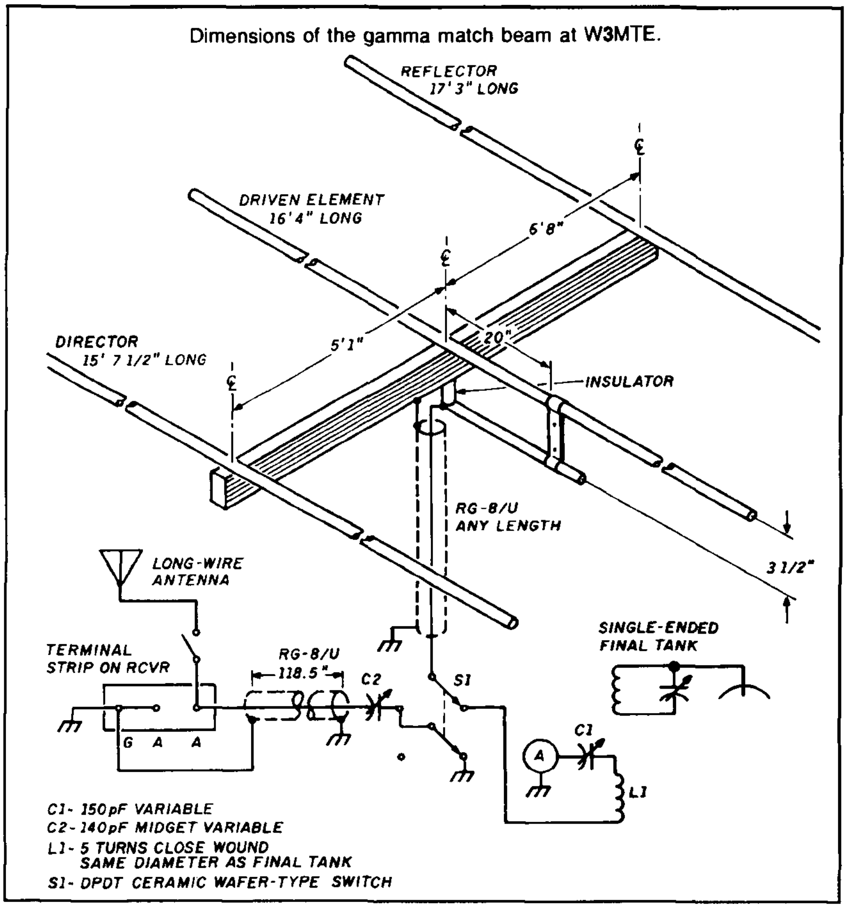
The gamma match program

The gamma program, written in BASIC by Richard Nelson, WBØIKN, is based upon W7ITB's analysis and designed for the Apple II+. It can be modified to work equally well with many microcomputers.[3]

I put the program to use designing a gamma match for a three-element, 10-meter Yagi. I took beam dimensions from my *Beam Antenna Handbook*.[4] Design frequency was 28.5 MHz. I planned to use a 1-inch diameter element, a 1/4-inch diameter gamma rod, 3-inch center-to-center spacing, and a 100-pF series capacitor (refer to **Figure 3**). Feedpoint impedance was estimated to be 18 ohms and I wanted to match to a 50-ohm line. When I plugged these values into the computer program, it indicated a gamma rod length of 22 inches and a series capacitance of 180 pF.

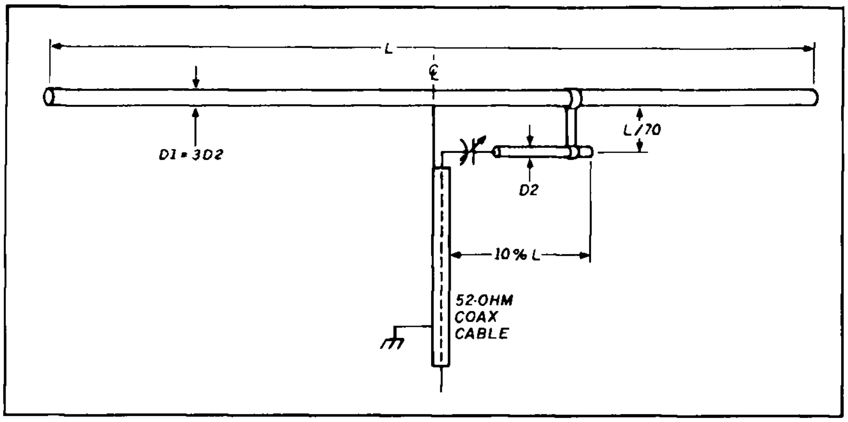
These results immediately rang an alarm bell. Our experiments had indicated that the series gamma capacitor should be about six times the operating frequency in meters and the gamma rod

FIGURE 1



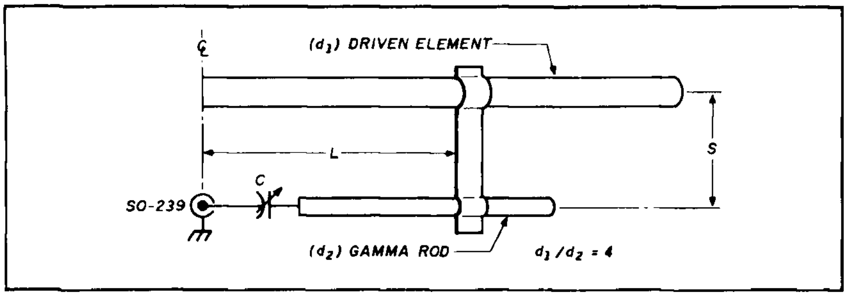
The early gamma match described by W3MTE (*QST*, September 1948).

FIGURE 2



Early *Radio Handbook* shows series gamma capacitor and approximate dimensions for gamma match.

FIGURE 3



W6SAI's 10-meter gamma match. Diameter d_1 = one inch, d_2 = 1/4 inch. Center-to-center spacing = 3 inches.

should be about 0.04 wavelength long. For the 10-meter band, this works out to a capacitor of 60 pF and a rod length of about 16 inches. To back up my assumption, I found a commercially produced 10-meter beam with substantially the same dimensions as my design, using a 19-inch gamma rod and a 45-pF capacitor. Not too close, but a lot closer than the answer ground out by the computer program!

Obviously, there was some factor I hadn't taken into account that influenced gamma dimensions. There was more to the gamma match than met the eye!

Gamma match computation

I found the answer to the puzzle in a short remark (almost an afterthought) in the text of the W7ITB computer program article.[1] Harold worked out gamma dimensions for a sample antenna and then mentioned that if the drive point impedance of the antenna had capacitive reactance, the value of the gamma capacitor would decrease, as would the length of the gamma rod. Armed with this morsel of information, I read the WBØIKN computer program again. At the end of the article the author mentioned that a smaller gamma capacitor may be used if radiator reactance is made capacitive (negative) by reducing its overall length.

Aha! Here was the missing clue. With a given value of drive point resistance, and a given gamma to driven element spacing, what would happen to the rod length and series capacitance values when different amounts of negative reactance were introduced into the driven element?

Varying the driven element reactance

For a given frequency, an antenna element may exhibit either positive or negative reactance at its drive point when the antenna is simply made longer or shorter than the resonant length. Shortening the element produces negative reactance; that's what I was interested in! I reran the WBØIKN program, plugging in various

values of negative reactance from j=0 to j=−50 (see **Figure 4**).

The plot shows that the series capacitance value peaks at the element resonant frequency (j=0) and decreases in value either side of resonance. The length of the gamma rod, however, follows a different curve. It exhibits the shortest length when the antenna exhibits negative reactance (−j15).

A practical gamma match system (one that can be built cheaply and adjusted easily) calls for the shortest gamma rod and the least amount of capacitance. It's no fun to hang from the top of a tower and try to adjust a gamma rod whose shorting bar isn't quite within reach!

You can build a small gamma capacitor inexpensively with a coaxial gamma rod that has the inner conductor serving as one capacitance element as shown in **Figure 5**.

In my case, a 22-inch adjustable gamma rod would work over a range of antenna reactance from j0 to −j50. However, as the antenna element approached resonance, the value of the gamma capacitance rose sharply, and the coaxial rod length didn't provide sufficient capacitance. From the plot, it was obvious that the designer of the manufactured antenna had cut his driven element shorter than resonance to provide a negative value of reactance (about −j30 ohms) in order to have reasonable gamma dimensions.

Gamma rod spacing

My next question was: what is the effect on gamma dimensions when element-to-rod spacing is varied? I used the computer program for the 10-meter beam element diameters; the results are summarized in **Table 1**. Rod length compared with spacing is given for four values of antenna reactance: j=0 (resonance), j=−15, j=−30 and j=−50 ohms.

Larger values of element-to-gamma spacing require a shorter rod length, but greater gamma capacitance. The shortest rod length is achieved when the driven element has a reactive value between −j15 and −j30, with an element-to-gamma spacing of 3 to 4 inches.

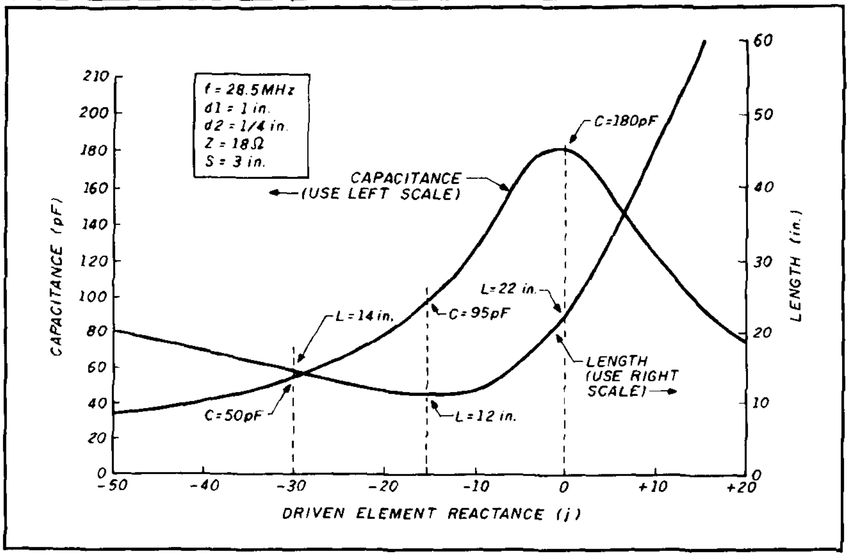
Gamma capacitance increases with element-to-gamma spacing, and decreases as the driven element exhibits greater values of negative reactance. Practical (small) values of capacitance are reached in the reactive region between −j30 and −j50.

Because shortening the driven element has minimal effect on beam performance, it would be helpful to choose a length providing a negative reactance of 30 to 50 ohms.

Element shortening

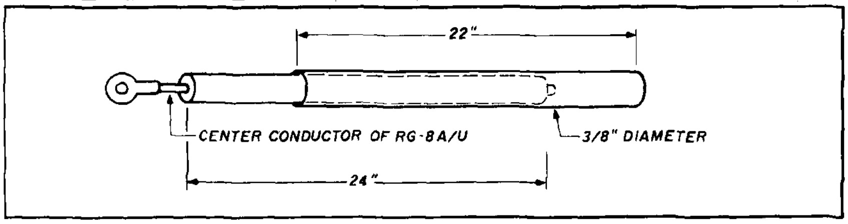
How much physical shortening is

FIGURE 4



Graph for determining design lengths of the gamma match.

FIGURE 5



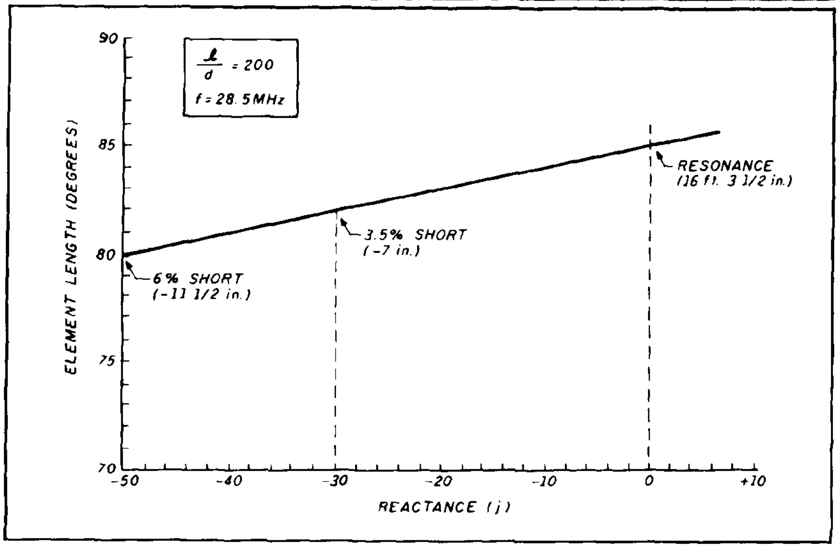
Coaxial gamma-rod capacitor for 10-meter beam. Maximum capacitance is about 55 pF.

TABLE 1

Various gamma and series capacitance values for different length driven elements.

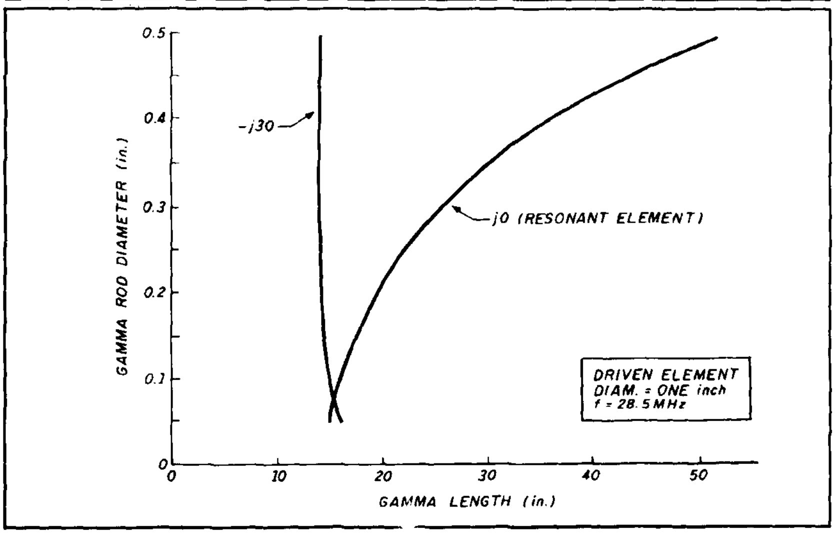
j	Spacing inches	Rod Length inches	Capacitance pF
j0	1	39	83
	2	25	145
	3	23	180
	4	22	212
−j15	1	33.5	57
	2	15	80
	3	12	95
	4	11	105
−j30	1	36	24
	2	18	31
	3	13	52
	4	12	58
−j50	1	36	22
	2	22	31
	3	20.5	32
	4	17	35

FIGURE 6



Tip-to-tip shortening required for various values of driven element reactance for 1-inch diameter element.

FIGURE 7



The length of the gamma rod with a shorter than resonant driven element (−j30) is nearly independent of gamma rod diameter.

required to provide a reactance of −30 to −50 ohms? It depends upon the ratio of element length to diameter. Such ratios have been computed and measured,[5] and a simplified plot for a length-to-diameter ratio of 200 is shown in **Figure 6**. This corresponds to a 1-inch diameter element at 28.5 MHz. To achieve a reactance value of −j30, you must shorten the driven element about 7 inches (tip to tip). For a reactance of −j50, you'll need a shortening of 11.5 inches.

Drive point impedance and element length

What happens to the 18-ohm figure if the driven element has a drive point value of 18 ohms at resonance and is shortened to provide a negative reactance? It decreases in value. The reduction depends upon the amount of shortening and the element diameter, as discussed previously. Assuming that the new resistance value is 15 ohms at a reactance value of −j50, a computer run shows that gamma rod length increases by an inch, and that the series capacitance decreases by 3 pF from the values determined for a feedpoint value of 18 ohms. This indicates that the actual feedpoint resistance isn't critical, and that the feedpoint values given in the literature for multi-element Yagi beams hold well for use in the gamma computer program.

Gamma rod diameter

The computer program provides interesting information about gamma rod diameters (see **Figures 7** and **8**). The curves show the importance of having a shorter than resonant driven element. With the −j30 element length, gamma rod length changes less than 2 inches as the rod diameter is varied from 0.05 to 0.5 inches. The gamma capacitor, given the same rod diameters, varies from 36 to 65 pF. When the driven element is resonant, the values of rod length and series capacitance vary largely. This gives further proof that adjustment of driven element length is of paramount importance in making the gamma match work.

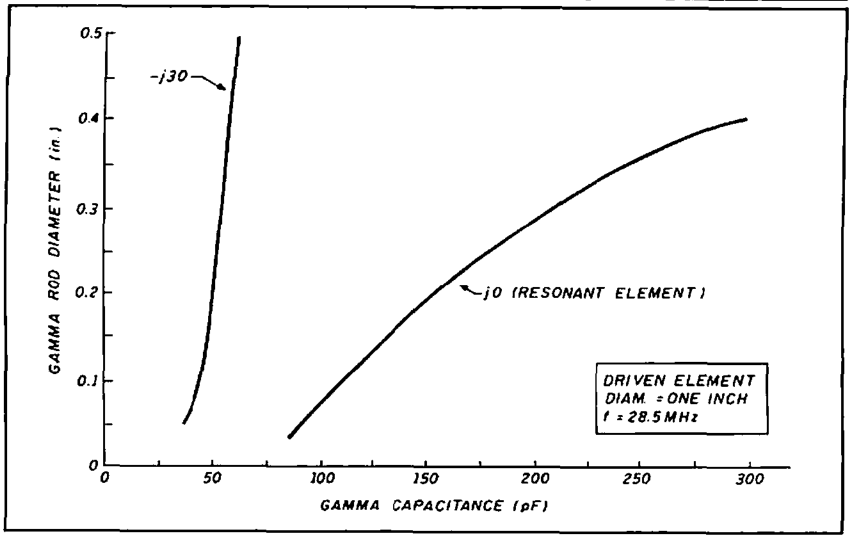
Frequency scaling

If all the dimensions of a 28.5-MHz beam and gamma match system are doubled, the computed results will be identical at half the frequency — or 14.25 MHz. This scaling isn't practical for my 10-meter beam; it would result in a 20-meter driven element diameter of 2 inches. I prefer a diameter of about 1.25 inches, all else being equal. I would probably also build a tapered element. The gamma match computer program doesn't consider this element, but there are programs that compute an equivalent element length for a tapered element.[6] This equivalent element can then be used with the gamma program once its length is readjusted to provide a reactive termination. Someday the Yagi computer program will be modified for frequency scaling. It will also accommodate the gamma match, as well as other matching systems requiring adjustment of the driven element length.

Is there pattern distortion with the gamma match?

The gamma match feeds only half the driven element. What happens to voltages and currents in the other half? Does the unbalanced feed system upset the beam pattern? Tests run by

FIGURE 8



Gamma capacitance is nearly independent of gamma length when shorter than resonant driven element (−j30) is used.

Katashi Nose, KH6IJ, show that voltage at the driven element tips ol a 20-meter Yagi isn't equal when a gamma match is used.[7] Even so, the azimuth pattern seemed balanced. Nose concluded that the voltage imbalance wasn't important.

Later tests run by Bob Sutherland, W6PO, a VHF "moonbounce" enthusiast, on a large array of 220-MHz gamma-fed Yagis showed that the array's pattern was normal with no noticeable "squint" or distortion that could be attributed to the gamma matches.

Gamma match summary

The gamma match provides a mechanically simple and easily adjusted network for matching a Yagi to a coaxial transmission line, provided the driven element of the array is somewhat shorter than the resonant length. This point has often been overlooked or not emphasized in the literature, leading to puzzling results.

For the best mechanical arrangement, make the capacitor part of the gamma rod, as shown in Figure 5. As they say in the world of computers, the gamma match is "user friendly." Information provided in this article, along with the gamma computer program, should make life easier for those contemplating using this interesting match system.

Electric stove RFI! (What next?)

My friend Wyn Wagener, W6VQD, called me the other evening to give me the latest news on the continuing RFI battle. He was concerned about the new electric ranges.

Old-style electric stoves have a multiple circuit heating element. The circuits are selected by a rotary switch that cuts the heating coils in and out, depending upon the cooking heat required. The newer electric ranges have dispensed with this common sense idea in favor of modern gimmicks and the results are questionable, to say the least.

The new brand of electric range has only one coil in the heating element and the circuit is cycled on and off by a continuously variable heal control, instead of a mullicontact switch. The control mechanism consists of a small rheostat in series with a low wattage heating element and bimetallic strip heat sensor. As you advance the control, the heater warms up and the strip cycles on and off. The strip controls the main heating element which, in turn, cycles on and off. Wyn discovered that some ovens created copious RFI during the cycling process, which can run in a sequence of 3 to 20-second on/off bursts.

Before he bought a new range for his home, Wyn took a portable receiver to the appliance store and monitored several ovens. Although there seem to

be many makes, it seemed to Wyn that there were only two manufacturers of the devices, regardless of the name tag — General Electric and Frigidaire. Extensive monitoring showed the General Electric manufactured ranges to be relatively free of RFI, but the Frigidaire ranges completely wiped out the shortwave spectrum during operation!

The RFI battle is an uphill fight and it gets very discouraging. My radar range wiped out all HF reception, jammed the TV receiver, and made the kitchen radio unusable. A call to the manufacturer brought the news that I could buy a line filter for the range at a modest price. I asked the sales representative why they didn't install the filter on the oven before it was sold. He told me that it was installed on all export models, because most overseas countries demanded it. However, since there was no comparable law in the United States, they didn't feel it was their duty to protect the local customer in this regard! Alas. Perhaps it's time for the FCC to take a more active role in RFI regulation, a role they have been noticeably successful in avoiding to date.

The "Dead Band" quiz

I want to thank those of you who took the time to write me about these little brain teasers. I really appreciate your letters and comments. I want to acknowledge the following who provided correct answers to past quizzes.

Submitting correct answers in the "black box five-terminal network" quiz are: Albert Weller, Jr., WD8KBW; Martin Woll, N6VI; Tim Bratton, K5RA; Les Hannibal; Lawrence Roy, KA1ADF; Arthur Erdman, W8VNX; Mike Czuhajewski, WA8MCQ; Harold Muensterman, N9DEO; and Clayton Dunnihoo, K5ESV.

There are several configurations that satisfy the problem, the simplest being five 0.5-ohm resistors arranged in a five-pointed star with a common center.

Those who found the solution to the "resistors in a jar" quiz were: Martin Woll, N6VI; Tim Bratton, K5RA; Harold Muensterman, N9DEO; and Clayton Dunnihoo, K5ESV. (The minimum resistor count is 419.)

A new "Dead Band" quiz

If we have many more of the complete HF blackouts experienced last spring, you should have plenty of time to solve this puzzle, submitted by Andy Loomis, KE0UL.

"A snowplow begins to clear a roadway at noon on a day during a steady snowfall. The plow moves two miles during the first hour and one mile during the second. What time did the snow begin to fall?"

Andy says, "This is not a trick question, nor is it a problem with a quick but not obvious solution. The fascination of the problem lies in the apparent lack of enough information given in the question itself."

Good luck! I'll send the reader who produces the first complete, correct answer to this quiz an autographed copy of the *Beam Antenna Handbook*. Send your answers to me at Box 7508, Menlo Park, California 94025. The decision of the judges is final. hr

Note The computer-produced curves shown in this article are in close agreement with earlier curves run with an RF bridge by John True, W4OO, as shown in "How to Design Shunt-fed Systems for Grounded Vertical Radiators," *Ham Radio*, May 1975, page 34

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3. Fred Sontag, N0CAO, "Gamma Matching Programs for the C-64/128," *Ham Radio*, May 1987, page 87
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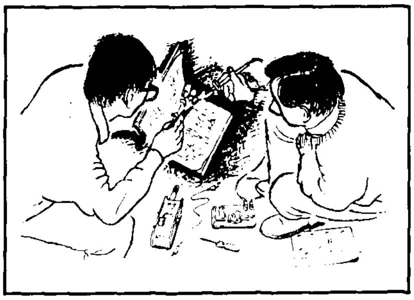
6. James L. Lawson, W2PV, *Yagi Antenna Design*, Chapter 7, American Radio Relay League, Newington, Connecticut
7. Katashi Nose, KH6IJ, "Notes on Parasitic Beams," *QST*, March 1960, page 43

Automatic Packet Beacon Tracker and Monitor



How often have you set your rig up on 20 or 10 meters to wait for the station you have traffic for, only to find the band isn't open to that area? You sit through countless hours of frustrating QRM, monitoring stations you're not interested in. PACTRACK.ASP, a script file I wrote for the Procomm Plus© terminal program (MS-DOS environment),* can help you overcome this trouble.

Written initially to monitor propagation conditions on the 10-meter band, PACTRACK.ASP will turn Procomm Plus into a powerful packet terminal program for the Kantronics KAM TNC™. It is easily modified for any of the other popular packet terminal units. To modify the script file for earlier versions of Procomm, change the carriage return character (^M) to an exclamation point (!). The program is written in the ASPECT script language, supported by Procomm.

Program features

Once you've loaded Procomm Plus, activate PACTRACK.ASP by entering ALT F5. The program will ask you for the name of the script file. (The .ASP extension isn't required.) A title screen appears, listing the stations the program has been modified to monitor. You'll be asked to turn on your printer. Disable this feature if you don't want to print the beacon stations heard. PACTRACK will now perform the following functions for you:

- Monitor for beacon or ID packets from the stations you have included in the program.
- Print out the time and date of reception when a station has been received, and give an indication that your UNPROTO CQ path has been changed to transmit through the station. (See **Figure 1**.)
- Turn on the beacon at the interval you have selected, if you have included the beacon option in the program.
- Print out the time, date, and call of the station with a notice that the station received was not listed, if you receive a beacon or ID packet from a station other than those included in the program.
- Allow modification of the program to send a connect request to a specific station once it has been received, rather than automatically change your UNPROTO path.

FIGURE 1

```
WDA
DAYTIME  01/28/89  13:51:37
cmd:WJ5V:VE2GOF/R VE2GOF-2/G VE2GOF-1/B VE2GOF-7/N
md:####UNPROTO IS NOW CQ V VE2GOF-7####TURN BEACON ON

VE2GOF<<<< TARGET STATION FOR BEACON #######

      ######CAUTION...BEACON IS NOW ON#######


WDA
DAYTIME  01/20/89  14:00:28
cmd:WB4HFQ>ID:WB4HFQ WB4HFQ-2/G WB4HFQ-1/B WB4HFQ-7/N
mc:###UNPROTO IS NOW CQ V WB4HFQ-7####TURN BEACON ON

WB4HFQ...QTH KY<<<< TARGET STATION FOR BEACON #######

      ######CAUTION...BEACON IS NOW ON#######


WDA
DAYTIME  01/28/89  14:10:15
cmd:COUNTY, LI, NY
        ######THE BEACON RECEIVED IS NOT LISTED######
```

Examples of printout using PACTRACK.ASP.

FIGURE 2

```
Alt-0  ID^M
Alt-1  $A^M
Alt-2  %A^M
Alt-3  ^C
Alt-4  CONV^M
Alt-5  D^MD^M
Alt-6  CMS ON^M
Alt-7  CMS OFF^M
Alt-8  GATE ON^M DIGI ON^M HID ON^M
Alt-9  GATE OFF^M DIGI OFF^M HID OFF^M
```

Procomm Plus keyboard macro screen with settings for packet radio.

Other Procomm features

Included in the Procomm Plus program is a keyboard macro screen which lets you set up the ALT 0-9 keys for your particular application. My keys are set up as shown in **Figure 2**. My keyboard macro, called KAM.KEY, is loaded automatically when the PACTRACK script file is called up.

Procomm also includes a "chat" mode. This is a split screen mode; the top three-quarters of the screen displays the received text, and the bottom quarter displays your transmitted text as entered from the keyboard. Entering ALT O activates the split screen option. I usually do this when I am communicating. You must activate full-duplex mode to use the split screen. You can accomplish this easily by entering ALT E; PACTRACK.ASP is loaded initially in the half-duplex mode and must be in half duplex to operate correctly. When you're finished with split screen mode, simply enter ESC to return to terminal mode and enter ALT E to return to half-duplex mode.

I'm looking forward to hearing from you experienced programmers regarding enhancements to PACTRACK. I'm not a programmer and this was my first attempt. However, the program runs very well and does what it was designed to do. For those who would prefer to send comments via packet radio, send them to W4GBB at WA4ONG in Richmond, Virginia.

If you don't want to type in the program, I'll send you the PACTRACK.ASP program and the keyboard macro file for $10. The Procomm Plus package is available from most local BBSs.* If you want to have the PACTRACK.ASP program customized for your particular application, include the following information:

- Call, QTH of the station(s) to be monitored

*Procomm Plus is a registered trademark of Datastorm Technologies, Inc., P.O. Box 1471 Columbia, Missouri 65205.

*Procomm is a user-supported product. It is not public domain, and is not free software. To become a registered user, send $25 for registration only, $35 for registration plus the latest version on disk, or $50 for registration plus the latest version and a printed, bound manual to the address listed. Procomm support BBS: (314)449-9401 24 hours a day, seven days a week.

- Printer or no printer
- Want beacon automatically turned on?
- Hard drive or floppy?
- Special beacon text
- Monitor for beacons or IDs?
- Information you want in your keyboard macro file

If you send me this information, I'll customize your program for the Kantronics KAM TNC.

Robert F. Cann, W4GBB

Editor's note: Send a no. 10 SASE to *Ham Radio* for a hard copy of the PACKTRACK ASP program and macro file

Mobile HT Audio — The Near Ultimate Solution

Many articles have been written describing schemes for improving the audio output from handheld transceivers, especially when operating mobile. The low output power leaves a lot to be desired when combined with vehicle and road noise. The usual fix involves building an external amplifier.

I've often wondered why I try listening to a 2-inch speaker driven by a few milliwatts of power while my car stereo system sits idle. Here's an easy, no modification required way, of using your car's audio system with your HT, for those of you with a built-in cassette player. I designed a cassette adapter that looks like a standard cassette tape with a cable that plugs into the HT's external speaker jack. You insert the adapter into the tape player as you would any standard cassette. I found out later from my son that my "creation" was already commercially available!

The device, marketed by Radio Shack as a "Compact Disc Cassette Adapter," is sold under catalog number 12-1951 for $19.95. It lets you play portable CD units through your cassette tape player. It comes equipped with a miniature stereo plug, the same size as the external speaker jack on my HT. When used in this manner, the HT will "play" through one channel of the stereo system.

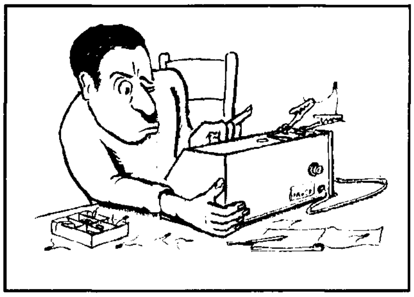
There are three simple ways of converting the adapter to a mono system so you can use both stereo channels:

- Use a mono-to-stereo adapter plug, like Radio Shack no. 274-368. This is the preferred method, since the unmodified unit will be available for use with a stereo source like a CD player. However, the size of the adapter plug may interfere with the external microphone plug on some HTs.
- Replace the stereo plug with a mono plug, paralleling both inputs. This is the most difficult modification to make, because you need to connect both inputs to a single mini-plug.
- Add a short jumper wire at the cable terminations on the pc board inside the cassette. (The board contains an RC network.) This involves removing six screws (two on the top and four on the bottom of the cassette), adding a jumper between the red and white cable leads, and reassembling the cassette.

Now you can enjoy HT mobiling with the audio available from your car stereo system, without modifying the HT or the car stereo. Use the tone controls to reduce hiss and enhance weak signals. You'll be amazed at how good an HT can sound.

Frank H. Finney, W9PXP

Practically Speaking



Joseph J. Carr, K4IPV

VERTICALLY POLARIZED HF ANTENNAS: PART 1

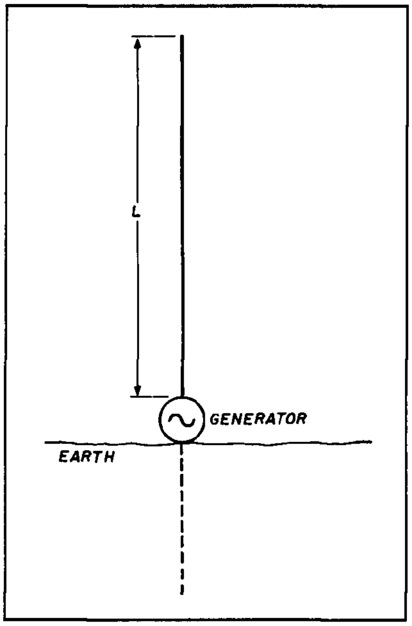
Antennas are a favorite topic for technical writers because our mailbags show that they're a very popular subject with readers. This month, and for the next two months, I'll discuss vertical antennas. Although the regard with which Amateurs view verticals varies from "tremendous" down to "little better radiator than a dummy load," the vertical remains popular. My own luck with verticals has been mostly good. The vertical is the antenna of choice for people living in cramped quarters that don't allow a beam antenna.

Will the vertical antenna work as well as a Yagi beam or quad up 100 feet? The answer is a qualified "maybe." The problem is context. For the DXer the beam is the hands-down favorite if money is no object. But in a situation where an omnidirectional horizontal pattern is needed, the beam suffers. So the correct answer to such a question is, "for what application?"

Because there are so many heated opinions regarding verticals, I take on this topic with some trepidation. Let's hope that a little more light than heat is generated. Keep in mind that it's possible your buddy's bad luck with a vertical might be due to not knowing how to design, build, and use one — or expecting something totally inappropriate from the antenna.

The polarity of an antenna is the direction of the electrical (E) field. Because the transmitted signal is an orthogonal electromagnetic wave, the magnetic field radiated from the antenna is at right angles to the electrical field. The direction of the electrical field, which sets the polarity of the antenna, is a function of the geometry of the radiator element. If the element is vertical, then the antenna polarity is also vertical. The signal propagates out from the radiator in all directions of azimuth, making this antenna an "omnidirectional" radiator

FIGURE 1A



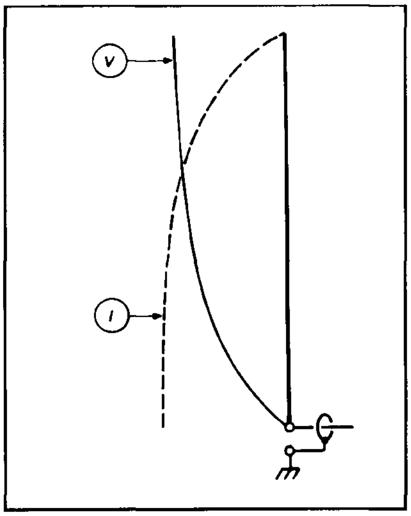
Basic concept of a vertical antenna.

Figure 1A shows the basic geometry of the vertical antenna: an RF generator (transmitter or transmission line from a transmitter) at the base of a radiator of length L. Although most commonly encountered verticals are quarter wavelength ($L = \lambda/4$), that length isn't the only permissible one. In fact, it may not even be the most desirable length. I'll talk about the standard quarter-wavelength vertical antenna here because it's so popular, and will also deal with other length verticals (both greater and less than quarter wavelength).

The quarter-wavelength vertical antenna can be modeled as half a dipole installed perpendicular to the ground, with the ground as the "other half" of the dipole. Because of this, some texts show the vertical with a dotted line "ghost radiator" in the earth beneath the main antenna element. **Figure 1B** shows the approximate current and voltage distribution for the quarter-wavelength vertical. Like the dipole, the quarter-wavelength vertical is fed at a current node, so the feedpoint impedance is at a minimum (typically 35 to 55 ohms, depending upon nearby objects). As a result, the current is maximum and the voltage is minimum at the feedpoint. As you'll see, however, not all vertical antennas are fed directly at the current node. As a result, some designs require antenna tuning units to make them match the antenna impedance to the transmitter output impedance.

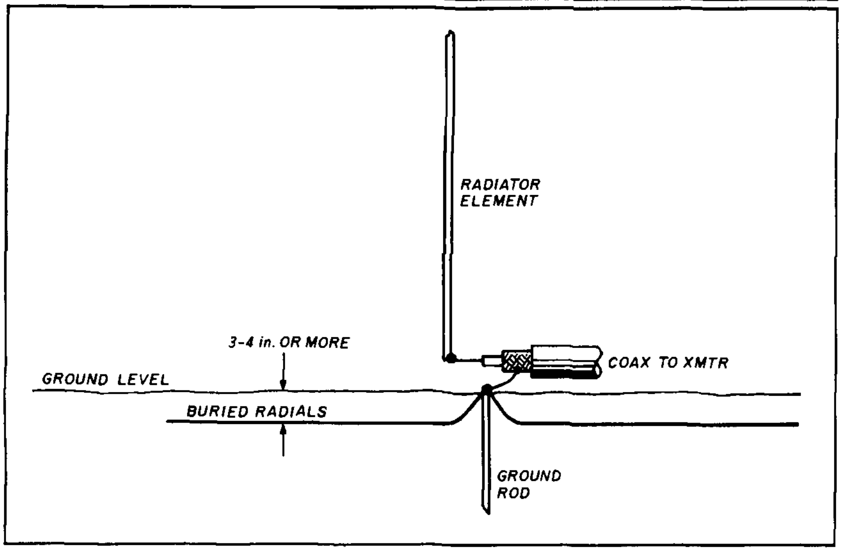
Figures 2A and **2B** show the two basic configurations for the HF vertical antenna. **Figure 2A** shows the ground-mounted vertical antenna. The radia-

FIGURE 1B



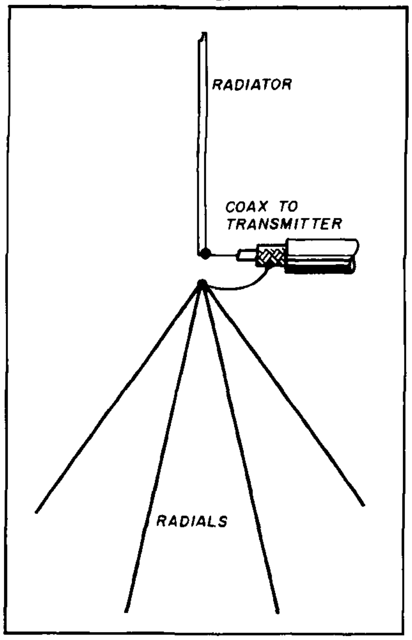
Approximate current and voltage distributions on a quarter-wave vertical.

FIGURE 2A



Basic ground-mounted HF vertical.

FIGURE 2B



A vertical with elevated radials.

tor element is mounted at ground level, but is insulated from ground. Because the antenna shown is a quarter wavelength, it's fed at a current node with 52-ohm coaxial cable. The inner conductor of the coaxial cable is connected to the radiator element, while the coaxial cable shield is connected to the ground. As you will see later, the ground system for the vertical antenna is critical to its performance. Normally, the feedpoint impedance isn't exactly 52 ohms, but somewhat lower. As a result, without some matching there will be a slight VSWR. But in most cases the VSWR is a tolerable tradeoff for simplicity. If the antenna has a feedpoint impedance of 37 ohms, the value usually quoted, then the VSWR will be 52 ohms/37 ohms, or 1.41:1.

A vertical mounted above the ground level is shown in **Figure 2B**. This antenna is as popular as the ground mounted. Amateurs find it easy to construct this form of antenna because the lightweight vertical can be mounted at reasonable heights (15 to 50 feet) using fairly inexpensive television antenna slip-up telescoping masts. A problem with the nonground level vertical antenna is that there's no easy way to connect it to ground. The solution to the problem is to create an artificial counterpoise ground with a system of quarter-wavelength radials.

In general, at least two radials are required for each band — and even that number is marginal. The standard wisdom holds that the greater the number of radials, the better the performance. While that statement is true,

FIGURE 2C

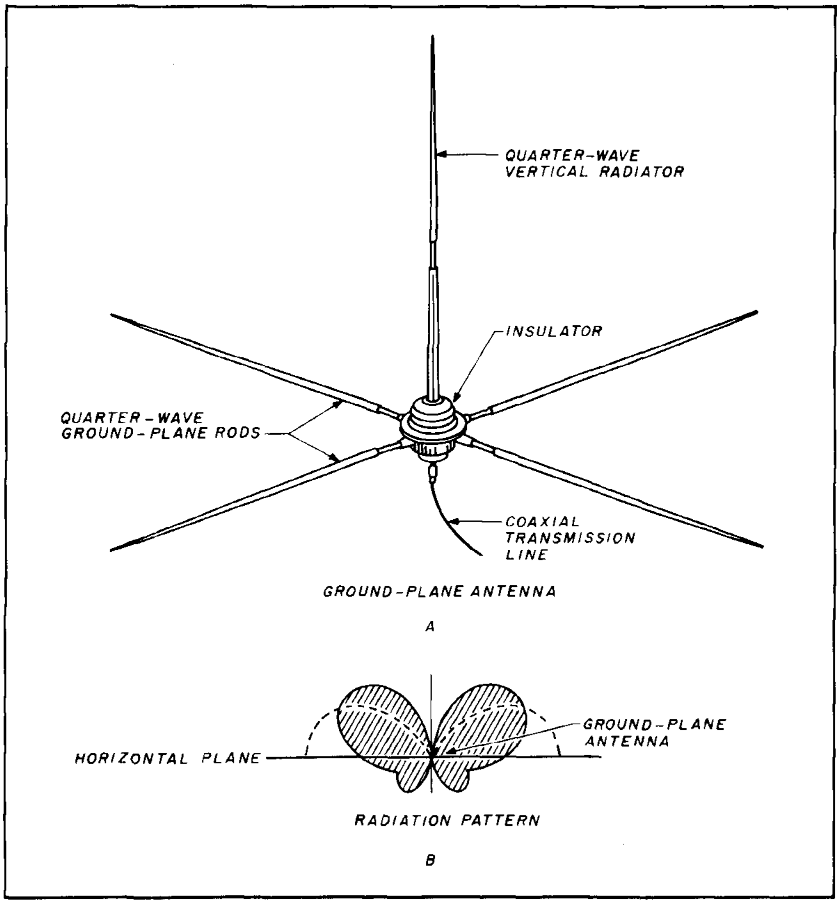


Diagram of a commercial ground plane with four radials mounted 90° *apart*.

there are both theoretical and practical limits to the number of radials. The theoretical limit is derived from the fact that more than 120 radials return practically no increase in operational effectiveness, and at more than 16 radials the returned added effectiveness per new radial is less than the case for fewer radials. That is, going from 16 to 32 radials (doubling the number) creates less of an increase in received field strength at a distant point than going from 8 to 16 radials (both represent doubling the density of the radial system).

The radials of the above-ground vertical antenna can be at any angle. In **Figure 2B** they are "drooping radials;" i.e., the angle is greater than 90 degrees relative to the vertical radiator element. Similarly, **Figure 2C** shows a vertical antenna equipped with radials at exactly 90 degrees. (No common antenna has radials of less than 90 degrees.) Both of these antennas are called ground-plane vertical antennas.

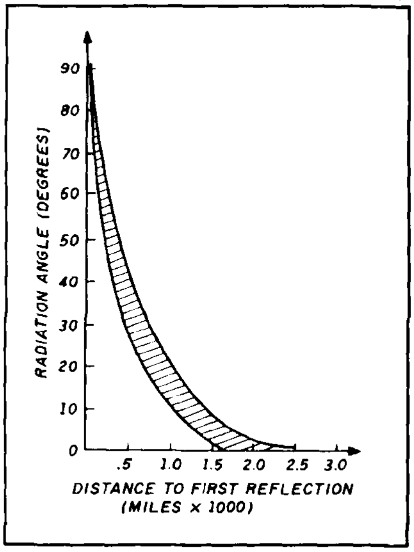
The angle of the radials is said to affect the feedpoint impedance and the angle of radiation of the vertical antenna. While those statements are undoubtedly true in some sense, there are other factors that also affect those parameters and are probably more important in most practical installations. Before digging further into the subject of vertical antennas, let's take a look at the subjects of angle of radiation and gain in vertical antennas.

Angle of radiation

Long distance propagation in the HF region depends upon the ionospheric phenomena called "skip." In this type of propagation, the signal leaves the transmitting antenna at angle a, called the angle of radiation, and enters the ionosphere where it is refracted back to earth at a distance from the transmitting station. The signal in the zone between the outer edge of the antenna's ground wave region and the distant skip point is weak or nonexistent.

The distance covered by the signal on each skip is a function of the angle of radiation. **Figure 3** shows a plot of the angle of radiation of the antenna, and the distance to the first skip zone. The angle referred to along the vertical axis is the angle of radiation away from the antenna relative to the horizon. For example, an angle of 10 degrees is elevated above the horizon 10 degrees. Shorter distances are found when the angle of radiation is increased. At an angle of about 30 degrees, for example, the distance per skip is only a few hundred miles.

FIGURE 3



Graph of skip zone versus angle of radiation.

Although you might expect to see a single line on the graph, there's actually a zone shown (shaded). This phenomenon exists because the ionosphere is found at different altitudes at different times of the day and different seasons of the year. Generally, however, in the absence of special event phenomena in the ionosphere, expect from 1500 to 2500 miles per bounce in the HF bands for low angles of radiation. Note, for example, that for a signal that's only a degree or two above the horizon, the skip distance is maximum.

At distances greater than those shown in **Figure 3**, the signal will make multiple hops. Given a situation where the skip distance is 2500 miles, covering a distance of 7500 miles requires three hops. Unfortunately, there's a signal strength loss of 3 to 6 dB on each hop, so you can expect the distant signal to be attenuated from making multiple hops between the earth's surface and the ionosphere. For maximizing distance, the angle of radiation needs to be minimized.

So what's the ideal angle of radiation? It's standard — but actually erroneous — wisdom among Amateur Radio operators (and even commercial operators, it turns out) that the lower the angle of radiation the better the antenna. This statement is only true if you're looking for long distance, so it reflects a strong bias toward the DX community. The correct answer to the question is: "It depends on where you want the signal to go." For example, I live in Virginia. If I want to work stations in the Carolinas or New England, it would behoove me to select a high angle of radiation for radio conditions represented in **Figure 3**, so that the signal will land in those regions. But if I want to work stations in Europe, Africa or South America, then a lower angle of radiation is required. Because of the difference between performance of high and low angles of radiation, some stations have two antennas for each band — one each for high and low angles of radiation.

Figure 4 shows a signal from a hypothetical antenna located at point O to show what angle is meant by angle of radiation. The beam from the antenna is elevated above the horizon (represented by the horizontal "tangent to horizon" line). The angle of radiation, a, is the angle between the tangent line and the center of the beam. This angle is not to be confused with the beamwidth, which is also an angle. In the case of beamwidth, I'm talking about the thickness of the main lobe of the signal between points where the field strength is 3 dB down from the maximum signal (which occurs at point P); these points are represented by points x and y in **Figure 4**. Thus, angle b is the beamwidth, while angle a is the angle of radiation.

FIGURE 4

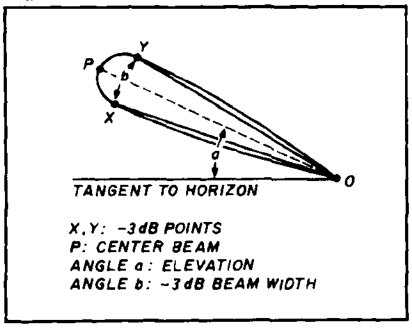


Diagram illustrating angle of radiation.

Gain in vertical antennas

Vertical antennas are known as omnidirectional because they radiate equally well in all directions. Gain in an

FIGURE 5

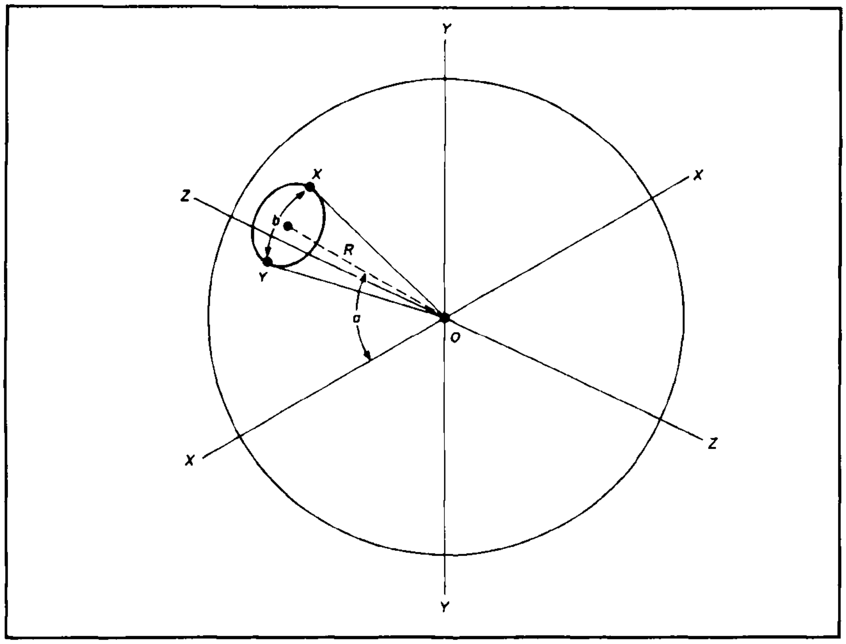
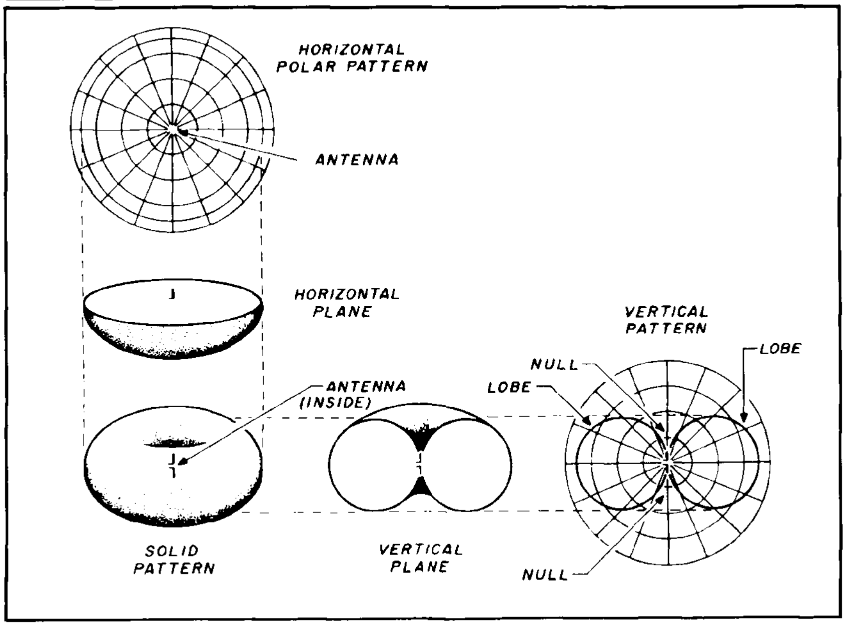


Diagram of a theoretical isotropic radiator.

FIGURE 6



E and H plane patterns of a typical vertical.

antenna is not the creation of power, but rather a simple refocusing of energy from all directions to a specific one. Therefore, gain implies directivity. According to the convention, then, the vertical antenna can't have any gain because it radiates in all directions equally, and gain implies directivity. Right? No, not really. Let's develop the theme more carefully.

Again consider the idea of an isotropic radiator (the word "isotropic" means equal power in all directions). Consider a spherical point source radiator located at point O in **Figure 5**. Whatever the level of power available from the transmitter, it will be spread equally well over the entire surface of the sphere as it radiates out into space away from point O. If you measure the power distributed over some area, A, at a distance, R, from the source, then the power available will be a fraction of the total power:

$$P_{avail} = \frac{\textit{Total Available Power} \times \textit{Area "A"}}{\textit{Total Surface Area of Sphere}} \quad (1)$$

or, in math symbols, we can write the expression:

$$P_a = \frac{P_s}{4\pi r^2} \quad (2)$$

Where:

P_a is the power available per solid degree

P_s is the total radiated power in watts

R is the radius of the sphere, i.e., the distance from O to P.

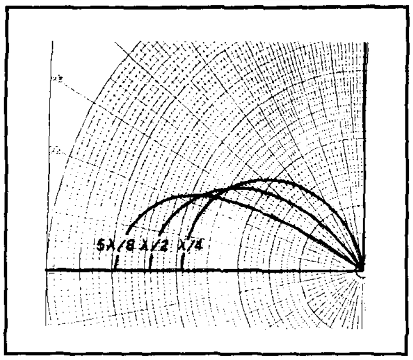
A practical rule of thumb for this problem is to calculate from the surface area of the sphere. If you perform the right calculations, you'll find that there are approximately 41,253 square degrees on the surface of a sphere. By calculating the surface area of the beam front (also in square degrees), you can find the power within that region.

Now for the matter of gain in a vertical antenna. The vertical isn't gainless because it doesn't radiate equally well in all directions. In fact, the vertical is quite directional except in the horizontal (azimuth) plane. **Figure 6** shows the radiation pattern of the typical vertical radiator. The pattern looks like a giant doughnut in free space (see solid pattern in **Figure 6**). When sliced like a bagel, the pattern is the familiar circular omnidirectional pattern. When examined in the vertical plane, however, the plane looks like a sliced figure eight. The gain comes from the fact that energy isn't spread over an entire sphere, but concentrated to the toroidal doughnut-shaped region shown. Therefore, the power per unit area is greater than for the isotropic (truly omnidirectional) case.

Non quarter-wavelength verticals

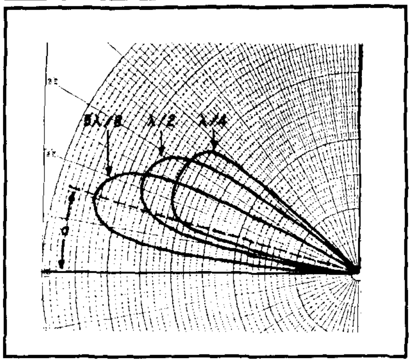
The angle of radiation for a vertical antenna, hence the shape of the hypothetical doughnut radiation pat-

FIGURE 7A



Approximate patterns for three different length verticals. Relative power gains are also visible.

FIGURE 7B



Effects of ground losses on the patterns of the same three antennas.

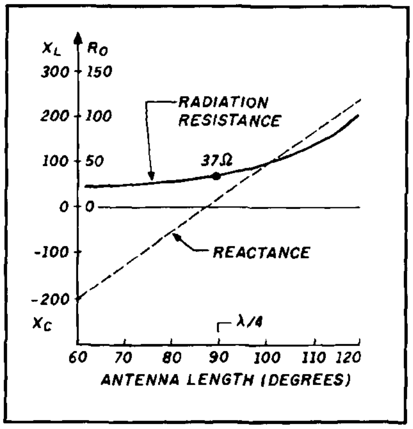
tern, is a function of the antenna length. (Note: "length" in terms of vertical antennas is the same as "height," and is sometimes expressed in degrees or wavelength, as well as feet and/or meters). **Figure 7A** shows the approximate patterns for three different length vertical antennas: quarter wavelength, half wavelength, and 5/8 wavelength. Note that the quarter-wavelength antenna has the highest angle of radiation, as well as the lowest gain of the three cases. The 5/8-wavelength antenna has both the lowest angle of radiation and the highest gain (compared with isotropic).

The patterns shown in **Figure 7A** assume a perfectly conducting ground underneath the antenna. However, that's not a possible situation for practical antennas — all real grounds are lossy. The effect of ground loss pulls the pattern in close to the ground (**Figure 7B**). Although all of the patterns are elevated from those of **Figure 7A**, the relationships still remain. The 5/8-wavelength radiator has the lowest angle of radiation and highest gain.

The feedpoint impedance of a vertical antenna is a function of the radiator length. For the standard quarter-wavelength antenna, the feedpoint radiation resistance is approximately 37 ohms, with only a very small reactance component. **Figures 8A** and **B** show the approximate feedpoint impedances for antennas from nearly zero effective length to 120 degrees of length.

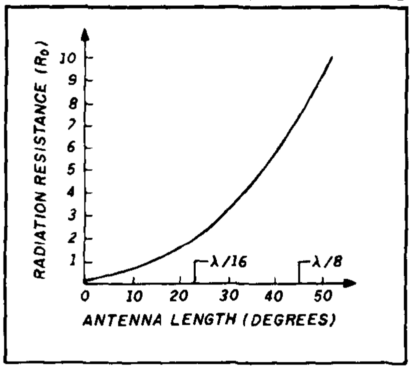
Antenna length as it is expressed in degrees derives from the fact that one wavelength equals 360 degrees. Thus, a quarter-wavelength antenna has a length of 360 degrees/4 = 90

FIGURE 8A



Approximate feedpoint impedances of antennas from 0° to 120° in electrical length.

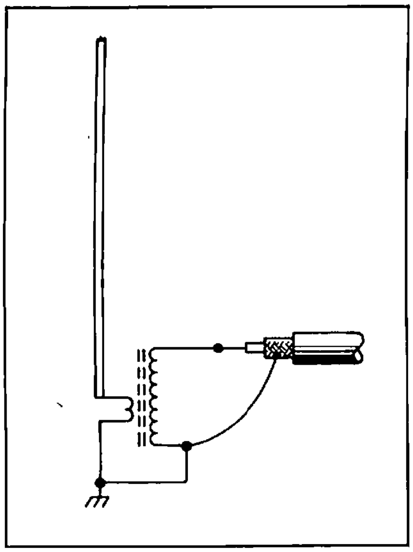
FIGURE 8B



Radiation resistance of antennas from 0° to 60° in electrical length.

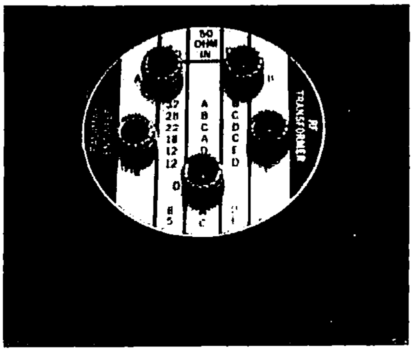
degrees. To convert any specific length from degrees to wavelengths, divide the length in degrees by 360. Thus, for a 90-degree antenna: 90 degrees/360 degrees = 1/4 wavelength. The graph in **Figure 8A** shows the antenna feed-

FIGURE 9



Basic connection of a toriodal transformer to a vertical antenna.

PHOTO A



Commercial impedance matching transformer.

point impedance, both reactance and radiation resistance, for antennas from 60 to 120 degrees; Figure 8B shows the radiation resistance for antennas from near zero to 60 degrees. Note that the radiation resistance for such short antennas is extremely small. For example, an antenna that is 30 degrees long (30/360 = 0.083 wavelength) has a resistance of approximately 3 ohms.

It's generally the practice on vertical antennas with an impedance-matching problem to use a broadband impedance-matching transformer to raise the impedance of these antennas to a higher value. Figure 9 shows the basic connection of the toroidal transformer to the vertical antenna. You can wind a homebrew transformer following instructions given in *The ARRL Handbook*, other publications, or a past issue of this column. You can also use a manufactured impedance transformer like the Palomar Engineers' model shown in Photo A. This transformer is designed specifically for HF vertical antennas.

Next month...

In the second installment of this three-part series I'll look at two topics: the installation of vertical antennas, and vertical antenna construction and mounting techniques.

I can be reached at POB 1099, Falls Church, Virginia 22041; I'd like to have your comments and suggestions for this column.

✓ 191

HAM RADIO Sweepstakes Winners List

Grand Prize Winner

W2KQI

First Prize Winners

WA1QWG	N4QBK
KM4KU	N8HWH
AF3Z	NJ4R
KA9RHN	WD4CBL
W4WZB	WB1FWS
W3IFL	N1AXR
KA1DNB	W2CJ
W6DFG	K1WXY
WA2EXG	N6FWS
K9PQT	KA1ONF
WA4GMX	WF5R
N2CDR	KA1QQA
WA0TRF	WA4DUP
W3FZT	K1VSJ
WA6CBQ	K1VUW
WA3END	WB1GMH
W2SWA	KE3R
WA2YNH	K1OPE
WA2VTP	WB3EFQ
K9FLX	K1TGE
W4JNK	WA2TPU
WA2FEB	K6QJ
KA0SFV	W1FVY
WB3BEF	WB9VFM
WA2SSJ	K2SYR
N0IBL	KB2LP
W0LOV	K1JG
WB2EZK	WB2DJQ
WA9SFH	WA3FIO
KU0L	K3RMF
W2URP	WA4RIP
N3GIU	K6MHQ
W6JEU	AH6CD
W4CVX	W6CKU
K7ZAB	K2AGI
WA9D	WA1GFY
WA4SLE	WA5NPT
KD3BZ	W0CSA
W4GDW	W2UJE
N5EGT	WA8ANP
N1FMD	W0DUI
W0FSK	W1VAB
N4NFT	KL7IF
W3TOL	K5SN
KC8MT	W5HSQ
K1YVZ	WD0CYH
W5JHY	K4AOR
KA1TW	K7ERG
W8BIT	K9JPQ
K2DGW	N9HCI

Elmer's Notebook

Tom McMullen, W1SL

VISUAL AIDS — LIQUID CRYSTAL DISPLAYS

In this last article in my series on visual aids, I'll look at a type of display used in a multitude of products — including watches, volt/ohm/milliammeters, computer screens, automotive monitoring systems, and transceivers. (The list is far too long to complete here.) It's called a liquid crystal display, or LCD. The beauty of this type of display is that it can be manufactured to show characters in any language, or to provide a visual symbol in any shape. It also uses very little power.

What's in it?

The principle used in the LCD comes from a laboratory device for exploring methods of electronically controlling light transmission. This experimental device is called a Kerr cell (see **Figures 1A** and **1B**). It works as a result of polarization. The input and output sides of the Kerr cell have a polarized coating which allows light with the same polarization as the coating to pass through it. When the liquid in the cell is polarized the same as the coating material, the light passes through. When voltage is applied to the electrodes, the liquid changes its polarization, and the light doesn't pass through (refer to **Figure 1B**).

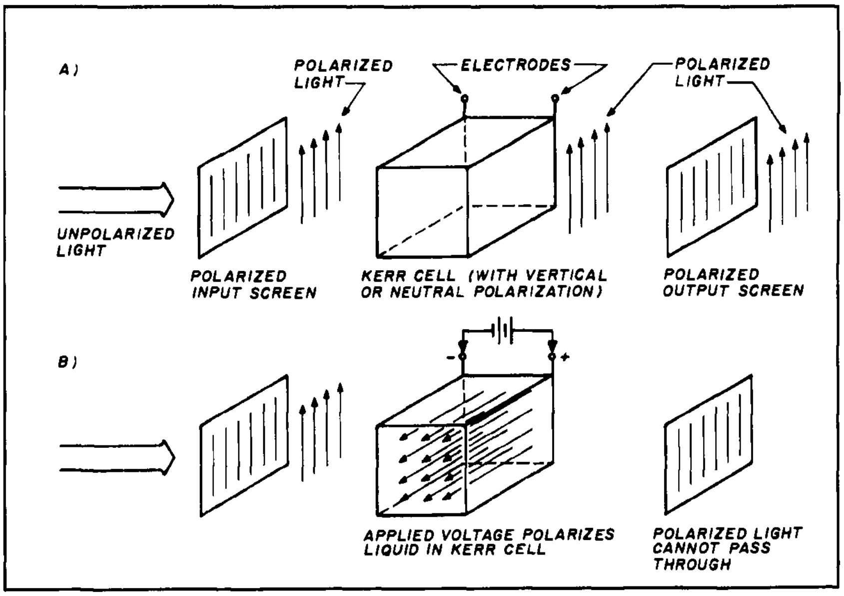
You can perform an experiment with polarized light using the lenses from a pair of sunglasses that have a polarized coating — plain tinted lenses won't work. Look at a light through both lenses, and rotate one lens as you do so. At some point, the light will decrease markedly or perhaps disappear. This is the point at which the lenses are polarized 90 degrees apart. A polarizing filter for photographic use works in a similar manner; glare and reflections are polarized to some extent, and when the filter is rotated, the glare can be reduced for improved photographs.

Putting theory to work

The Kerr cell is a bulky apparatus; it's most useful in laboratory and other experimental uses. The modern LCD is an adaptation of this principle that can be small enough to use in a wrist watch, or large enough to display many lines of text or graphics on a laptop computer

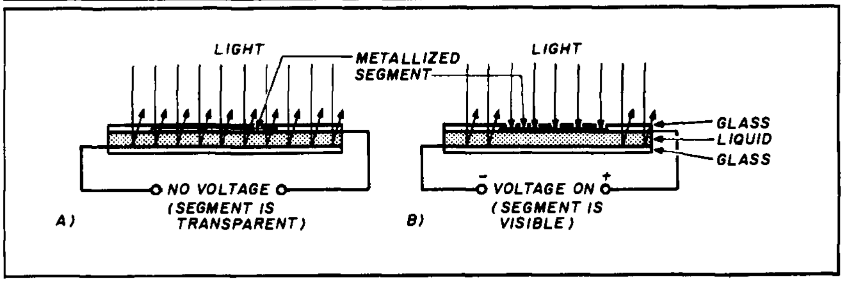
A basic LCD element is shown in **Figure 2**. It consists of two pieces of glass with a liquid sandwiched between. The inner surface of each piece of glass is coated with a very thin metallic layer which serves as an electrical contact, and will allow light to pass. In its normal, unexcited state the liquid isn't polarized (see **Figure 2A**).

FIGURE 1



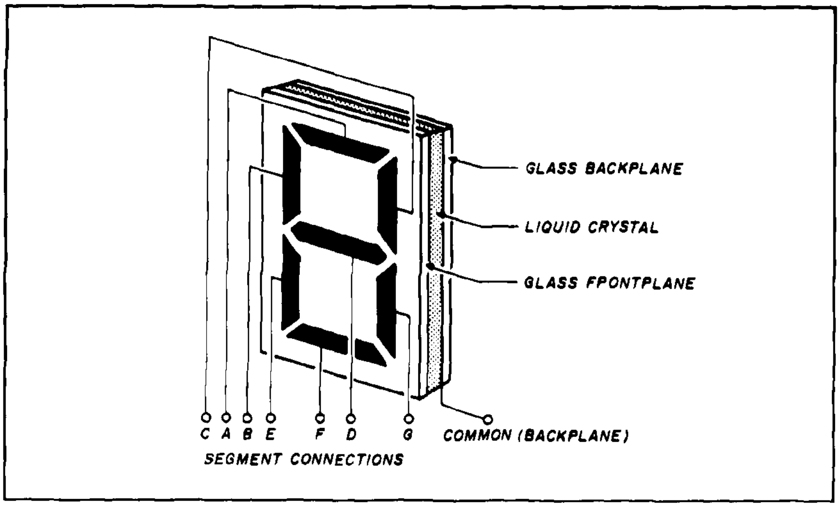
The predecessor for today's LCD was the Kerr Cell shown here in a simplified view. A liquid in the cell could be polarized by applying a voltage. When the polarization of the crystal-line structure in the liquid was different from the light entering the cell, output was decreased.

FIGURE 2



The LCD used on most devices today is a sandwich of glass with a liquid crystal material between. The glass has thin metallic layers for electrical contact.

FIGURE 3



A common seven-segment readout element as used in many numeric applications today. A simple, inexpensive driver IC activates the proper segments to form numbers.

When voltage is applied to the metallic layer, the crystalline structure in the liquid changes direction (polarization) and stops the light. Most LCDs depend upon reflected light; when you view the display from the front, you see the outline of whatever shape the metallic segment has as a silhouette against the reflective backplane Figure 2B.

In its simplest form (in clocks, watches, calculators, and other strictly numeric readout devices) each segment of a number is a conducting transparent layer connected to a contact — much the same as the LED seven-segment display I described last month. **Figure 3** shows a seven-segment LCD readout display. A simple decoder IC can drive the desired segments to form a number. Some LCDs have a large number of segments and can form letters as well as numbers, in what's called an alphanumeric display.

Complex characters

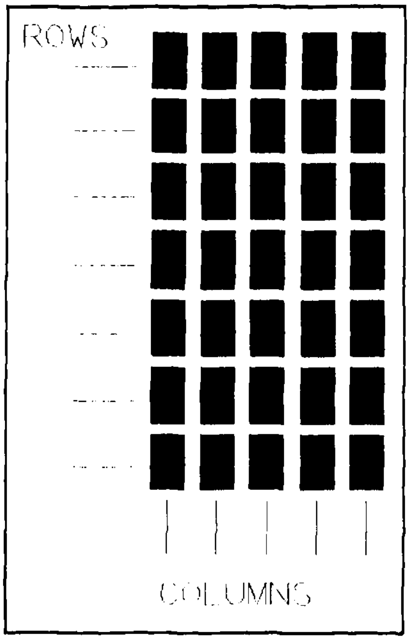
Even greater versatility is obtained by forming the characters with an array of dots that can be turned on or off individually. This type of readout is called a dot-matrix LCD. The dot pattern is often five or six dots wide and seven or eight dots high, but there are many other possibilities. **Figure 4** shows an example of a 5 × 7 matrix.

This type of display requires a more sophisticated driver. It operates by decoding the incoming data and deciding which rows or columns to energize for the pattern required. **Figure 5** shows the letter N. It's formed by first activating all the rows (0 through 6) along with column 0. The driver then activates row 4 and column 1, row 3 and column 2, row 2 and column 3, and finally rows 0 through 6 and column 4. The polarity of the liquid (actually, in many devices it's almost a jelly) behind each dot changes, shutting off the reflected light. What you see is the dark letter against a light background.

What keeps the first vertical column of the N from disappearing while the driver is working on the rest of the letter? Once you have "turned on" polarized liquid, it stays that way until another voltage application turns it off. This is where the low power consumption advantage comes in. You don't need to keep voltage on the segment all the time — just refresh it once in a while with another pulse of voltage to keep it from fading away. Without refreshing, LCDs fade after a while; some inexpensive ones disappear in a few minutes, but better ones last much longer. They change gradually from black, to grey, to clear.

Of course, the more dots you have the more metallic contacts you need, and the more complex the driver circuitry must be. Modern microprocessors and driver ICs can handle this with ease. Multiple digit readouts use a technique called "strobing." The driver turns on the correct dots or segments in the first character, then goes to the next one and activates it, and so

FIGURE 4

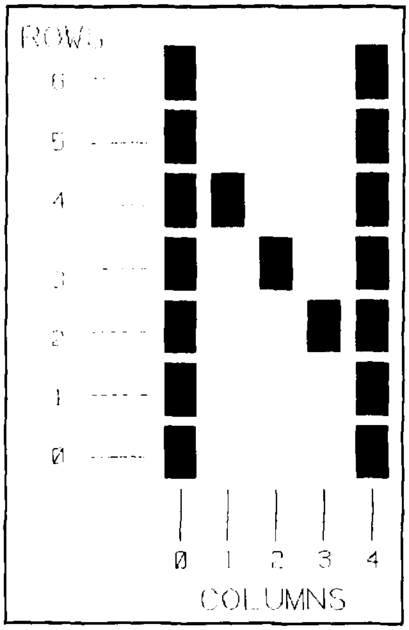


An array of dots forms a matrix for complex characters. This array is five dots wide by seven dots high; many other combinations are possible.

on, until all characters are active.

If there are multiple lines (as there are on a computer screen), the driver can work on one line after the other. It moves down the screen so fast that

FIGURE 5



The letter "N" formed by activating the correct rows and columns of a dot-matrix display. See text.

your eye doesn't see any flicker, then returns to the top to either refresh the first line of characters or to make changes in it.

Of course all these metaled spots, rows, and columns require connections to the outside world so the driver circuits can apply voltage. There are a large number of connections at the edge of the glass readout device, and these are somewhat fragile. However, most LCD assemblies are packaged in such a way that you can't damage them if you take reasonable care. Flexible ribbon cable is often used to make connections between the LCD and the rest of the circuits. LCDs do have the slight disadvantage of being temperature sensitive. People traveling in cold climates are accustomed to seeing the wrong time on their automotive clocks until the heater has warmed the passenger compartment, and the liquid in the LCD has thawed enough to respond to voltage pulses. The electronics for the clock continue to work normally, so when the LCD thaws out it suddenly shows the correct time. Latest advances in LCD technology have produced displays in many colors; you'll see them in some of the newer Amateur transceivers, and some computer screens. An item that caught my eye just recently was a book-sized AM/FM/TV receiver with a flip-up screen. The screen was an LCD approximately 4 × 5 inches, showing a color TV program in amazing clarity. What an improvement compared to the first color TV set I saw. It took two people to move, and used three cathode-ray tubes and filters to produce a color image. The modern LCD version fits in a briefcase and has a better picture too!

Coming in my next column — what you can do with simple, inexpensive instrumentation. **hr**

✓ 175

✓ 174

PRODUCT REVIEW

Morse Code Tutor Program

"Morse: The Code Machine" by Laresco, a morse code tutor for Apple II series and C-64 computers, is designed to teach code recognition and build speed. It can be used by someone preparing for the Novice exam, anyone who wants to upgrade, or by the ham who simply wants to increase code speed. There are 12 different software packages available, from the basic Fundamental to the "all frills" Elite+. Each successive version of the program includes more modes and features. Purchasing a code oscillator lets you take advantage of the manual's code sending lessons.

The Fundamental package is a "bare bones" version of the program. It generates code sounds for characters in text memory. No characters are displayed on the screen. You practice writing the characters on paper for the code you hear. After completing the session, you can view the text in memory and compare it with what you wrote.

I worked with the Elite+ version. It has three learning modes: teach, drill, and practice. Each mode is broken down into sections which let you tailor your learning experience and concentrate on your weakest areas. The manual suggests you use all three modes in two daily sessions for the best possible code workout.

Teach mode concentrates on basic Morse code recognition. You can use any one of five different teaching modes. Each concentrates on getting you to connect the letter with its particular code sounds. Code can be self- or machine generated.

In *drill mode*, you work to increase your recognition of what you've learned in *teach mode*. Characters or code sounds are generated by the computer and stored in a buffer. You have the option of matching the character with the code, or the code with the character, by hitting the appropriate key on the keyboard. The computer corrects you when you make a mistake.

After you've worked with the teach and drill modes, you can improve your code recognition speed with practice mode. This mode allows you to practice what you've learned using self- or computer-generated text.

Depending on which package you purchase, text can be typed in or loaded from a DOS 3.3 disk file. You also have the option of saving text memory to disk or viewing text memory on the screen. All packages allow you to choose extended sound spacing (i.e., spacing between dots and dashes within a character) and transmission tone frequency; the "+" packages also have extended character and word spacing capabilities. The more complex packages include color graphics, but you don't need a color monitor to use the graphics modes. The Fundamental and Fundamental + versions come with an 18-page abbreviated manual. All other packages come with a 33-page detailed manual which describes all the modes and features, and includes basic lesson plans. For more information on the different packages and their capabilities contact Laresco, POB 2018, 1200 Ring Road, Calumet City, Illinois, 60409. Phone (312)891-3279.

It took me a few hours of playing around with the program and its various options to realize all it could do for me. I'm not very "computer literate" so there were a few things that I had to learn by trial and error. My biggest mistake was in not taking the time to sit down and read the manual thoroughly.

On the whole, however, I think the "Code Machine" is a useful tool for learning the code. Depending on the package you choose, you have several different ways to learn. But you don't have to take my word for it! My eight-year-old son dropped by my office while I was playing with the program. Within 15 minutes of using "Morse: The Code Machine," he recognized many more letters than he had when he started and it took some persuading so I could get in on the fun too!

de KA1STC

NEW PRODUCTS

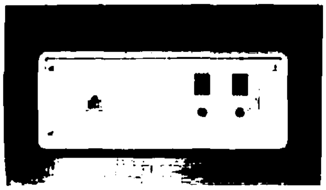
Packet Talker

Engineering Consulting announces the "Packet Talker" model PKTA for the Commodore 64 and compatible computers. The PKTA uses software to convert ASCII messages into speech. Messages can be stored in bulletin board format for up to 300 users; they can be retrieved by preassigned touchtone access commands. Each message is spoken over the air from the computer's voice synthesizer. Use the Packet Talker with repeater controllers to add a talking packet bulletin board, or hear messages from a personal mobile packet terminal.

The PKTA can link a packet TNC with any voice repeater. Hardware and software are provided for interfacing to the C-64. Audio from the TNC and PTT circuits of the transceiver combine with the computer's voice allowing conventional packet communications and voice retrieval of messages on request.

A similar option (PK8 and PK1) is available for Ultra ComShack 64 repeater controllers. When used with the Ultra, the Packet Talker allows complete repeater control, remote screen transfer of all active parameters, voice messages, and remote programming of all parameters from any off-site TNC terminal.

The model PKTA Packet Talker sells for $189.95 and is available from Engineering Consulting, 583 Candlewood Street, Brea, California 92621. Phone (714)671-2009 or FAX (714)255-9984.



New Field Calibration Power Sensor

Bird Electronic Corporation has announced the model 4029 Power Sensor Calibrator for use with their 4420 series RF power meters. With a CRT terminal or a PC with a serial port, the 4029 provides in-field calibration of 4420 power meters to within ±3 percent of a known RF standard.

The 4029 supplies a menu-driven protocol to the terminal to aid in the calibration process. You drive a 4020 series RF power sensor connected to the calibrator with a known amount of RF power at a specific frequency, and enter the power level into the terminal keyboard. The calibrator calculates and stores a correction factor in the power sensor's memory for that frequency.

Bird also has the model 4024 Directional Power Sensor, the latest addition to the 4020 series of Thruline® design RF sensors. The frequency range of the unit is 1.5 to 32 MHz at up to 10 kW. Other sensors in the series cover ranges from 1.8 to 32 MHz and 25 to 1000 MHz at up to 1 kW. All 4020 models are unconditionally guaranteed for life.

For further information contact Bird Electronic Corporation, 30303 Aurora Road, Cleveland (Solon), Ohio 44139. Phone (216)248-1200.

Circle #301 on Reader Service Card.

AVCOM's PSA-65A Portable Spectrum Analyzer

AVCOM introduces its portable spectrum analyzer, model PSA-65A. It covers frequencies through 1000 MHz in one sweep with a sensitivity greater than −90 dBm at narrow spans. The lightweight battery or line-operated spectrum analyzer is for two-way radio, cellular, cable, and other uses. Options include frequency extenders to enable the PSA-65A to be used at Satcom and higher frequencies, audio demod for monitoring, log periodic antennas, and carrying case. For brochure and spec sheet contact AVCOM of VA, Inc., 500 Southlake Boulevard, Richmond, Virginia 23236. Phone (804)794-2500, FAX (804)794-8284, or TLX 70-1545 AVCOM UD.

Circle #302 on Reader Service Card.

Antenna Specialists Company Catalog

The Antenna Specialists Company has released a new Amateur Radio products catalog, no. HM-1001. It lists over 30 models of mobile antennas, base antennas, power dividers, and RF power amplifiers. Included are the patented DURA-FLEX® neoprene elastomer shock spring models, and On-Glass® window mount mobile antennas. A copy of the catalog is available from The Antenna Specialists Company, 30500 Bruce Industrial Parkway, Cleveland, Ohio 44139-3996. Phone: (216)349-8400 or FAX (216)349-8407.

Circle #303 on Reader Service Card.

Phillips Drivers Tooled for Foreign Electronics

Jensen Tools offers a set of six Phillips screwdrivers tooled for Japanese, European, and other foreign equipment. These Telvac drivers are made of hardened steel with standard grip, acid-resistant plastic handles. The set, priced at $12.95, is featured in Jensen's free 1989/90 catalog.

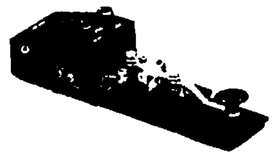
For more information write or call Jensen Tools, Inc., 7815 S. 46th Street, Phoenix, Arizona 85044. Phone: (602)968-6231.

Circle #304 on Reader Service Card.

MFJ Offers Code Practice Oscillator

MFJ Enterprises, Inc., announces its new MFJ-557 deluxe code practice oscillator for $24.95. It features a straight Morse key and a code oscillator with a built-in speaker, mounted together on a non-skid heavy steel base. A volume control lets you adjust it from barely audible to full sound. A tone control gives you a wide tone adjustment. An earphone jack is included.

The oscillator runs on a 9-volt battery (not included) or 110 volts AC with an optional power supply ($9.95) that plugs into a jack on the side of the MFJ-557. The straight key features screw-adjustable contacts and can be hooked to your transmitter and used for sending code over the air. The measures 8-1/2 × 2-1/4 × 3-3/4 inches. It comes with MFJ's one-year unconditional guarantee.



For more information contact MFJ Enterprises, Inc., PO Box 494, Mississippi State, Mississippi 39762. Phone: (601)323-5869. To order, call toll free (800)647-1800.

Circle #305 on Reader Service Card.

New Software Logging Program

"Hamlog" is a new modular auto-logging software program by Ernest Sandoe, KA1AWH.

This stand-alone user friendly program has over 17 modules and can be supplied to run in Turbo BASIC or MS/PC BASIC for IBM compatibles. It works well on 64K.

"Hamlog" is also available for over 130 different computers using the CP/M operating system, and for Apple computers using Apple BASIC.

An optional QSL label writing program is available for $5 plus $2 shipping and handling.

Send $24.95 ($19.95 for Apple version) to Ernest Sandoe, KA1AWH, POB 2015, Peabody, Massachusetts 01960. (Massachusetts residents include 5-percent sales tax.)

Circle #306 on Reader Service Card.

AUTOMATIC ROTOR BRAKE DELAY

Thomas V. Cefalo, Jr., WA1SPI, 29 Oak Street, Winchester, Massachusetts 01801

The immediate brake engagement that may occur when a rotation motor is de-energized is a problem common to some rotors. It doesn't usually present much trouble with a light antenna load, but with larger loads the additional stress applied to the rotor and the tower can be damaging. To avoid this possibility, manufacturers have incorporated a separate brake control into their rotor control units which lets the operator manually operate the brake. This solves the problem for the most part, unless the operator should accidentally engage the brake while the antenna is turning.

I've designed a circuit that automatically delays the rotor brake, giving the antenna time to stop turning. I'll describe its operation and construction here.

Theory of operation

The circuit shown in **Figure 1** is used with a Cornell-Dubilier HAM II/CD44 rotor system. The circuit is run by a separate power supply. Using the separate power supply cuts down on the number of modifications you need to make to the control unit, and leaves the original circuitry pretty much intact. I used CMOS integrated circuits to reduce the power requirements and provide a higher noise immunity.

Delay circuit operation is simple and straightforward. NAND gates and a multivibrator are the main components performing the delay function. The logic timing diagram is shown in **Figure 2**.

The brake switch is connected to a latch composed of two NAND gates (U2A and U2B) to debounce the switch contacts. U1 is a multivibrator configured for monostable operation and triggered from the rising edge of a pulse. One output of the latch (pin 3) is connected to the positive trigger input of the multivibrator. The gate inputs for U2C of brake relay RY1 are connected to pin 3 of the latch and the inverted output $\overline{Q}$ of the multivibrator. When the brake switch is depressed, pin 3 of the latch transitions to a low, which forces the output of U2C to a high state. This causes transistor Q1 to become forward biased, turning on brake relay RY1. The relay contacts are connected in series with the primary of the rotor control unit's power transformer, disengaging the brake when power is applied.

The other output of the latch (pin 4) is connected to the switching transistor Q2 of the second relay RY2. This relay guarantees that the rotor's motor is switched off when the brake switch is released. When the brake switch is depressed, pin 4 of the latch transitions from a low to a high. This forward biases the transistor turning on RY2, making power available to the rotation motor's direction switches. You can rotate the antenna with the brake disengaged by depressing the control unit direction switches.

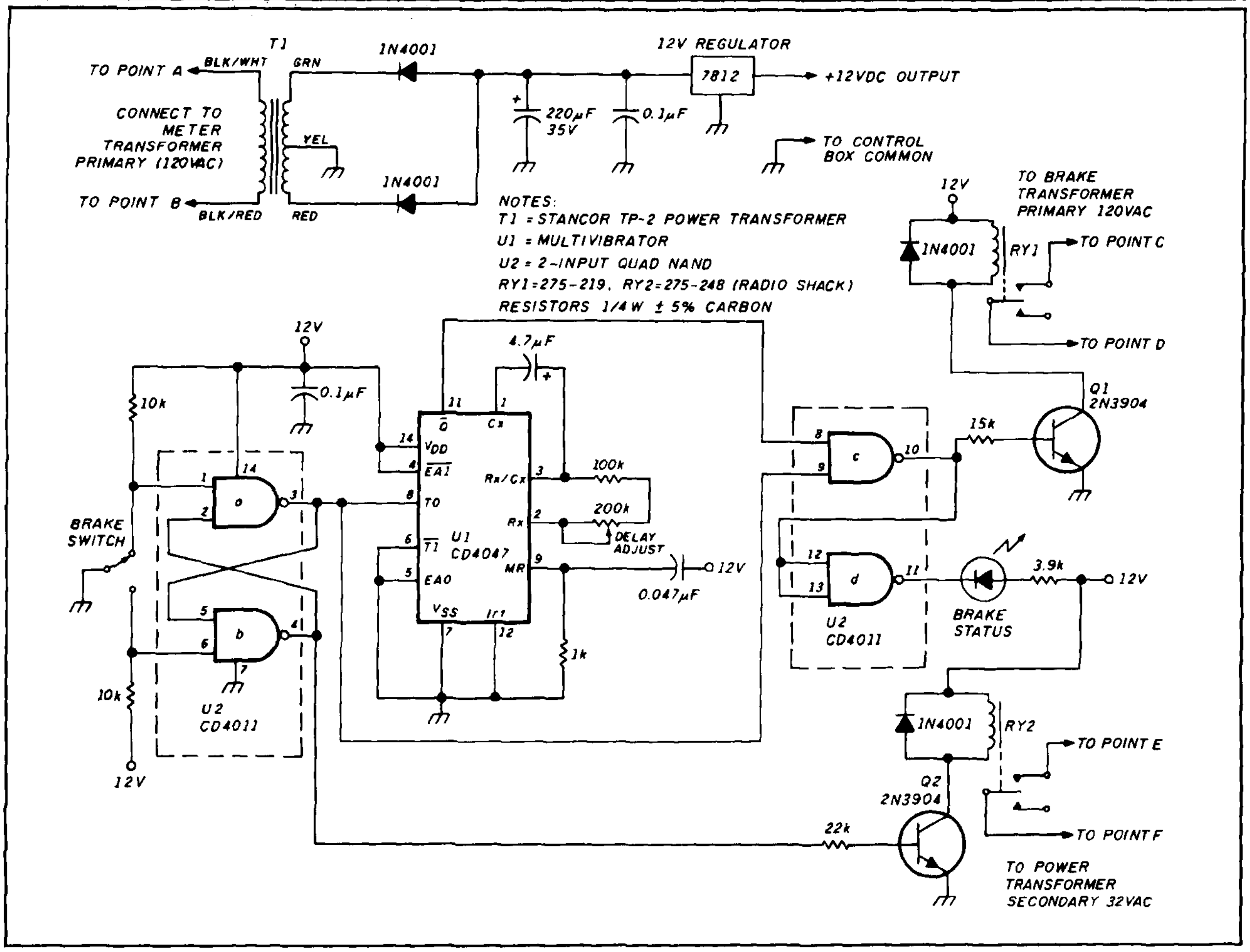
The direction and brake switch can be released simultaneously, just as the antenna reaches the location you've chosen. As you release the brake switch, pin 4 of the latch transitions to a low level; this switches RY2 off and disconnects the power to the motor. At the same time, pin 3 of the latch transitions to a high level. The multivibrator triggers from the rising edge, causing $\overline{Q}$ to pulse (see **Figure 2**). The external timing capacitor and resistor determine the width of the pulse and the brake remains disengaged for the duration. When the pulse-timing constant has elapsed, $\overline{Q}$ switches back to a high level and the output of U2C transitions to a low. This turns the brake relay off, and the brake engages.

The brake is delayed by the width of the multivibrator's pulse. Because the antenna has stopped turning in the meantime, no damage is caused when the brake engages. You can adjust the delay from approximately 1 to 3.5 seconds. Use the following guidelines: $Cx > 1000$ pF, and $10\text{ k} < Rx < 1$ meg, to obtain other delay times from **Equation 1**.

$$Td = 2.48 \times Rx \times Cx \qquad (1)$$

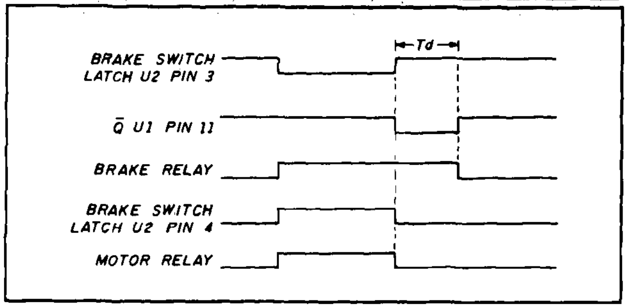
To prevent the brake from disengaging on power-up, I connected an RC network to the master reset input (pin 9 of U1). This network generates a pulse when power is first applied, causing the multivibrator to reset. This forces $\overline{Q}$ to remain high. I've also included an LED, which indicates the status of the brake.

FIGURE 1



Brake delay and power-supply schematic.

FIGURE 2



Logic timing diagram.

The power supply is a standard full-wave center-tapped rectifier with a secondary rating of 26-volts CT. It provides a maximum current of 150 mA. The delaying circuit draws a maximum current of 106 mA. Use any type of power supply that fits in the control box and supplies the current required by the delay circuit.

Construction

I built the circuit on a 3-1/2″ × 2″ vector pc board using point-to-point wiring. Both the delaying circuit and the power supply (except for transformer T1) reside on the vector board. I inserted push-in type solder lugs into the board to provide a point for external wire connections.

I mounted the transformer in the upper section of the control unit's chassis on two 1/4″ standoffs. I placed it at the end of the switching levels next to the meter transformer. The pc board is attached to the bottom of the chassis under the meter transformer with four 1/4″ standoffs.

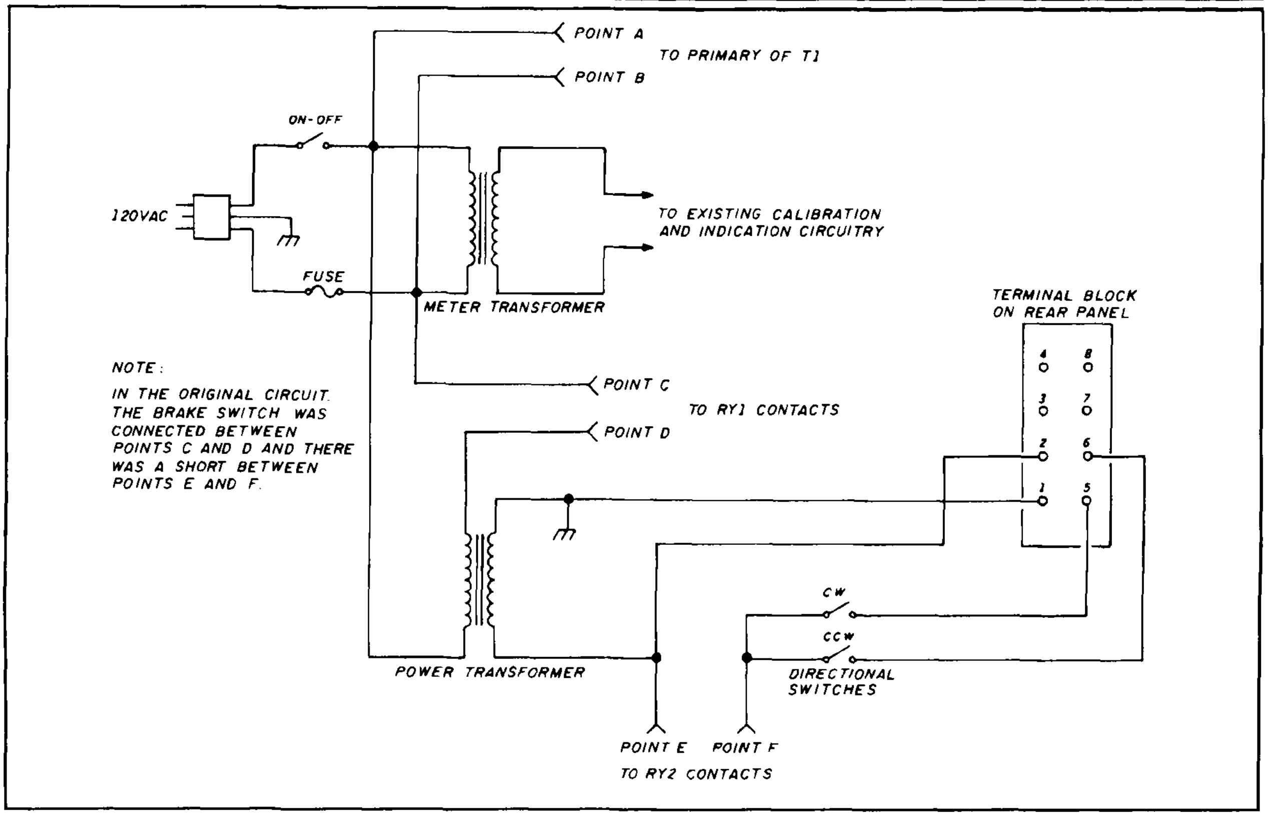
You can mount the brake status LED on the front panel. If you put it between the on/off and calibration switch it will be convenient and easy to see.

Wiring

Figure 3 shows the wiring details for installing the delaying circuit into the control unit. Remove the two wires from the brake switch and connect them to the RY1 contacts. Connect the common side of the brake switch to ground. Run a wire from the normally open terminal of the brake switch to pin 6 of U2B, and connect a wire from the normally closed terminal to pin 1 of U2A.

Locate the wire connected to the common terminal of both direction switches. Remove this wire from the direction switch and attach it to one of the switching contacts on RY2. Run a

FIGURE 3



Control unit wiring modifications.

wire between the other contact on RY2 and the common terminal of both direction switches.

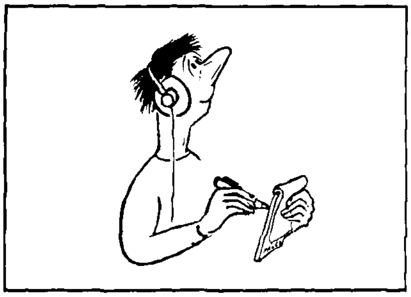
Connect the primary leads of power transformer T1* in parallel with the primary of the meter transformer. Now connect the secondary leads of T1 and the leads for the LED to the pc board. Finally, mount the common ground of the delay circuit to the control unit's chassis ground and the system is ready to use.

Conclusion

The delay circuit provides a simple solution to a problem that could result in some costly damage to your antenna system. The circuit prolongs rotor life because it eliminates the stresses associated with sudden stops. From the operator's standpoint, the control unit operates just as it did originally; however, the brake can no longer be accidentally or incorrectly engaged.

The modifications have a minimal impact on the control unit and the circuit is easy to build and install. Although the system I described is used with the CD44, you can adapt the circuit for other rotor systems using controllable brakes.

*Radio Shack carries a transformer (P/N 273-1366) rated at 25.2 volts CT at 450 mA. Digi-Key carries a similar transformer (P/N T105-ND) rated at 28 volts CT at 160 mA. *Ed.*



Garth Stonehocker, K0RYW

DXING DURING THE SUMMER QRN SEASON

An estimated 3600 thunderstorms are in progress around the world at any given time. They occur mostly in the tropical regions. These thunderstorms can be classified as air mass, frontal, or combinations of the two, depending on how they form. The main source of summertime QRN is the air mass thunderstorm.

During the evening DXing hours, air mass thunderstorm QRN may limit the usefulness of low band signals for local ragchewing and, for the most part, will rule out weak signal DX. The QRN, propagated from equatorial land regions or closer, increases the overall average noise level on the 80 and 160-meter bands. This happens because the "tropical" regions get closer to those of us in the Northern Hemisphere as the sun comes up to 23°N in the summer. As a result, a hop or two is cut from the thunderstorm noise propagation distance, adding a few dB to the overall noise. Florida leads the top thunderstorm producers of the closer areas; the eastern side of the Rocky Mountains in Colorado and Nebraska is next, followed by the southeastern part of the United States.

The air mass thunderstorm forms when the sun heats the ground. As the heat from the ground rises, it warms the air above, causing it to rise. As this heated air meets the colder air above, its moisture content condenses, forming clouds. The clouds — some of which are seized by the winds and carried into the jet stream to form the characteristic anvil-shaped top of a thunderhead at 30,000 to 40,000 feet — continue to rise until their condensed moisture forms drops heavy enough to fall as rain. Some drops are carried further upward and freeze into hail. This fast up-and-down motion generates static electricity strong enough to cause the air (as an insulator) to break down between a cloud and the earth, or between one cloud and another. As the lightning stroke releases this energy, it produces electromagnetic pulses. Our receivers pick up the HF radio frequency pulses we call "noise." Most air mass storms form on afternoons when the humidity is above 50 percent, and last into the night before cooling off enough to dissipate. Air mass thunderstorms linger for several days until they release their moisture as rain, or slowly move on.

How can you communicate with DX stations on these lower bands? Directional antennas may help if the thunderstorm activity is in the opposite direction from the DX stations. If you can avoid pointing your beam at these areas, you can help minimize noise pickup. In fact, if you can get the back of the antenna pointed in that direction, you can use the front-to-back ratio (typically 15 dB) to further decrease noise pickup. This may mean working DX long path or over the Pole. If the ionosphere will support propagation in that direction, and no geomagnetic field disturbance is occurring, you may find this a solution to some of the summer noise problems. You may also want to change your operating hours. Since most air mass thunderstorms dissipate during the night and build to noise proportions with the heat that arrives after dawn each day, there's a minimum noise period from about 3 to 8 a.m. which offers good operating conditions.

Last-minute forecast

The higher frequency bands are expected to be best the third and fourth weeks of August, when the solar flux increases the MUF for long skip openings. Don't expect many transequatorial openings in the evenings during the summer months. Sporadic E (E_S) short skip openings at midday should give the highest E region MUF in many years. Lower frequency signal strengths will decrease during daylight hours when the flux is high. Higher noise will also lead to poor conditions. Look for the best signals the first two and last weeks of the month. Thunderstorm noise will still be a problem in the evenings. Sporadic E short skip openings around sunset should help signals get through the noise.

Band-by-band summary

Six-meter sporadic E short skip conditions on some days will last anywhere from 30 minutes to a couple of hours *around local noon*. Expect about 1000 miles per hop.

Ten, 12, 15, and 17 meters will have quite a few short skip Es openings and some long skip openings during the 27-day solar flux peak to southern areas of the world, in the daylight hours. Fifteen and 17 meters will be best for several hours as the MUF decreases for the evening.

Twenty, 30, and 40 meters will be useful for DX communications to most eastern, western, and northern areas of the world during daylight hours and into the evening most days, via long skip to 2000 miles per hop or short skip Es, with 1000-mile hops. The period of daylight is still relatively long, but will be noticeably shorter by the end of the month.

Thirty, 40, 80, and 160 meters are all good for nighttime DX, even though the background noise will be severe in the evenings. The direction of the openings will rotate from the east to the south and then westward in the morning. If you want to avoid thunderstorm QRN, you may find sporadic E propagation helpful in the early evening toward the east and south. Try the early morning hours for communication paths to the west, and monitor WWVH or WWV on 2.5 and 5 MHz as beacons.

WESTERN USA

GMT	PDT	N	NE	E	SE	S	SW	W	NW
0000	5:00	12	17	15	10	10	10	10	10
0100	6:00	10	20	15	10	10	10	10	10
0200	7:00	10	20	15	10	10	10	10	10
0300	8:00	12	17	17	10	12	10	10	10
0400	9:00	12	15	17	12	15	10	10	10
0500	10:00	15	17	15	12	20	10	10	12
0600	11:00	15	17	12	15	20	10	10	15
0700	12:00	17	20	12	15	20	10	10	15
0800	1:00	20	20	15	15	20	10	10	17
0900	2:00	20	20	15	17	20	10	10	17
1000	3:00	20	20	15	20	20	12	12	17
1100	4:00	30	15	15	15	20	15	15	20
1200	5:00	17	15	10	15	20	15	15	20
1300	6:00	15	12	10	12	20	15	15	30
1400	7:00	15	12	10	10	30	17	17	20
1500	8:00	15	10	10	10	30	17	17	20
1600	9:00	17	10	10	10	20	17	17	20
1700	10:00	20	10	10	10	15	15	17	30
1800	11:00	20	12	10	10	12	10	17	17
1900	12:00	20	12	10	10	10	10	12	15
2000	1:00	20	12	10	10	10	10	10	15
2100	2:00	17	15	10	10	10	10	10	12
2200	3:00	15	15	12	10	10	10	10	12
2300	4:00	15	15	12	10	10	10	10	10
	UGUST	EAST	OPE	RICA	IERICA	ARCTICA	ZEALAND	ANIA TRALIA	N

MID USA

MDT	N	NE	E	SE	S	SW	W	NW	CDT
6:00	15	17	15	10	10	10	10	10	7:00
7:00	12	20	15	10	10	10	10	10	8:00
6:00	10	20	15	10	12	10	10	10	9:00
9:00	12	20	17	10	12	10	10	10	10:00
10:00	15	17	17	12	15	10	10	10	11:00
11:00	17	17	17	12	20	10	10	12	12:00
12:00	20	20	15	15	20	10	10	15	1:00
1:00	20	20	15	15	20	10	10	17	2:00
2:00	20	30	15	15	20	10	10	17	3:00
3:00	20	20	15	17	20	12	12	17	4:00
4:00	20	17	15	20	20	15	15	20	5:00
5:00	17	15	10	17	20	15	15	20	6:00
6:00	15	15	10	17	20	15	15	30	7:00
7:00	15	12	10	15	30	17	15	15	8:00
8:00	15	12	10	10	30	17	17	17	9:00
9:00	15	10	10	10	30	17	17	17	10:00
10:00	17	10	10	10	20	17	17	20	11:00
11:00	20	10	10	10	15	15	17	20	12:00
12:00	20	10	10	10	12	10	17	30	1:00
1:00	20	10	10	10	10	10	12	15	2:00
2:00	20	10	10	10	10	10	10	15	3:00
3:00	17	10	10	10	10	10	10	12	4:00
4:00	15	15	12	10	10	10	10	10	5:00
5:00	15	15	12	10	10	10	10	10	6:00
	EAST	OPE	RICA	IERICA	ARCTICA	ZEALAND	ANIA TRALIA	N	

EASTERN USA

EDT	N	NE	E	SE	S	SW	W	NW
8:00	15	17	15	10	10	10	10	10
9:00	15	20	15	10	12	10	10	10
10:00	17	20	15	10	12	10	10	10
11:00	17	20	17	10	15	10	10	10
12:00	20	30	17	12	20	10	10	10
1:00	20	20	17	15	20	10	10	10
2:00	20	20	15	15	20	10	10	20
3:00	20	30	15	15	20	12	12	20
4:00	15	17	17	15	20	15	15	20
5:00	15	15	15	17	20	15	15	20
6:00	15	15	10	17	20	15	15	15
7:00	12	12	10	15	20	17	17	15
8:00	10	12	10	10	30	15	15	17
9:00	10	12	10	10	30	15	15	17
10:00	12	10	10	10	30	15	17	20
11:00	15	10	10	10	17	17	17	20
12:00	15	10	10	10	15	17	17	20
1:00	17	10	10	10	12	15	17	20
2:00	20	12	10	10	12	10	17	20
3:00	20	12	10	10	10	10	10	15
4:00	20	12	10	10	10	10	10	15
5:00	30	15	10	10	10	10	10	12
6:00	17	15	12	10	10	10	10	10
7:00	15	17	12	10	10	10	10	10
	EAST	OPE	RICA	BBEAN ERICA	ARCTICA	ZEALAND	ANIA TRALIA	N

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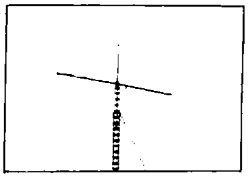
NEW HAM RADIO

HAM RADIO

SEPTEMBER 1989
Volume 22, Number 9

Tom McMullen, W1SL, is on vacation this month. His "Elmer's Notebook" column returns next month.



W6SAI, page 20

K4IPV, page 62

FEATURES

DEPARTMENTS

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Backscatter

More Cause for Thought

Last November I talked about the potential health hazards of electromagnetic radiation. While there is good reason to be concerned, too little is known at this time to determine if there is a direct link between electromagnetic radiation and cancer, or other diseases. Within the last few months, however, the story has received broad coverage in a number of different sources.

Paul Brodeur, author of *The Zapping of America* published in 1977, recently had a three-part series published in *The New Yorker* magazine on June 12th, 19th, and 26th that discusses the alleged hazards of electromagnetic (EM) radiation at length. Brodeur addresses a number of areas he feels are potential problems. They are: high voltage power lines, electrical wiring, radar, and video display terminals (VDTs).

High voltage power lines are a threat due to the high level electromagnetic field that surrounds them. Brodeur quotes research that claims these electromagnetic fields could alter the body's intricate, disease-fighting immune system and weaken its ability to destroy cancer cells.

Brodeur takes the Air Force to task for locating its PAVE PAWS radars near two major population areas — Cape Cod, Massachusetts and Sacramento, California — without having completed a study of the bioeffects of those radars. Finally, there is the ubiquitous computer VDT. Again, the threat is from various types of high level EM radiation.

Brodeur's series will be published this fall by Simon and Schuster as *Currents of Death: Power Lines, Computer Terminals and the Attempt to Cover Up Their Threat to Your Health*. Unfortunately, the sensational title does little to enhance the stature of Brodeur's piece.

Picking up on Brodeur's lead, both *TIME* and *NEWSWEEK* have run reports on EM radiation threats. The *NEWSWEEK* piece, published in its July 10th issue on page 77, was titled "An Electromagnetic Storm," with the subhead "Overblown charges about power lines and VDTs." Quoting from the article, "The reality is a bit more complicated. Scientists are only beginning to fathom the body's exquisite sensitivity to electromagnetic energy. The evidence linking exposure to disease is far less than Brodeur implies." Summing up, the article says: "Brodeur and many of those he criticizes seem to agree: we're not quite sure what we're up against, and we need urgently to find out." *TIME*'s piece ran in the July 17th issue and discusses many of the same points. The Department of Energy does not have enough information at this time to take any regulatory action regarding electromagnetic fields. If there is a link between certain illnesses, *TIME* asserts that appliances and electronic equipment will need to be redesigned, homes rewired, and the power distribution infrastructure completely rebuilt.

The New York Times ran a long article in its Tuesday, July 11th, "Science Times" section. While shedding little new light on the subject, the *Times* piece gives the reader a better explanation of the potential risks, and includes suggestions on how to limit exposure to electromagnetic fields. *The Times* also emphasizes that "prudence over panic" is the best course of action to follow.

I have also just received a press release from Congress's Office of Technology Assessment (OTA), dated Monday, June 19th, that discusses possible biologic effects of electromagnetic radiation. The report states that a number of different studies have demonstrated that "under specific circumstances even weak electric and magnetic fields can affect living cells and systems."

The OTA points out, however, that the health risk is much more complex and uncertain than that from other hazards like toxic chemicals and other known carcinogenic (cancer-causing) substances. Researchers do not know what parameters are the most important — "field strength, change in field strength over time, currents induced in the body, exposure, duration, or some other variation."

The OTA calls for careful work to establish, beyond a reasonable doubt, whether or not there is a relationship between certain illnesses and electromagnetic fields. The valuable 102-page OTA report is titled *Biological Effects of Power Frequency Electric and Magnetic Fields*. It is available from the U.S. Government Printing Office (GPO), Superintendent of Documents, Washington, DC 20402, stock #052-003-01152-2, for $4.75. Another important document, *Health Effects of Transmission Lines*, covers many types of EM radiation. The 393-page report is available from the GPO for $11. Ask for stock #052-070-06461-7, serial no. 100-22.

Finally, the ARRL Southwestern Division Convention, scheduled for August 25th-27th in Los Angeles, California, will be holding the first-ever Physician's Panel on Radiation Hazards. Wayne Overbeck, Ph.D., N6NB, will be the moderator The panel consists of:

- W. Ross Adey, M.D., K6UI, internationally respected scientist in bioeffects research. Dr. Adey is the recipient of prestigious

(Continued on page 89.)

Comments

Documenting extraordinary accomplishments

Dear HR

Your article on the "Bloody Beams" was great — not only from its technical perspective, but also knowing how one or two clear thinking individuals can win out over the "it's impossible/we can't do that" establishment.

Perhaps with your encouragement United States hams who played a key role in World War II electronics could document their experiences. One story that hasn't been written is how we achieved the extraordinary quality/functionality of *our* electronic equipment? This is something that we have now lost to the Japanese.

Dr. William H. Taubert
V.P., Beatrice/Hunt-Wesson, Inc.
Fullerton, California

The right formula

Just a note to let you know I think you have hit upon the right mix in articles. Referring to May 1989 issue of *HR*, I see everything from soup to nuts in way of construction articles — from the complicated to the simple, which is the way it should be. Carry on.

John L. McDonald, W6SDM,
Camarillo, California

Initiation rites

Dear HR

Is it possible that some of us do not have an aptitude for the code?

Psychologists tell us that the two hemispheres of the brain serve different functions. The left hemisphere is supposed to deal with analytical processes while the right side deals with speech, music, art, and the like. As one who can't dance, find the beat in rock music, or copy code well, I believe that code, like music is a right-brain activity. The theory portion of the exam is a left-brain process. To be a "good" amateur, one must have talents that some of us were not born with.

I started to try to learn the code in 1948. By 1953, I got a Novice ticket. I built a working 8-tube superhet receiver and a 75-watt transmitter. Alas, I could not copy off-air code, and never made a Novice contact. In 1956, after getting my First-Class Radiotelephone ticket, I also passed my Technician exam. I worked 6-meter phone, but no CW. My Technician license expired in 1961 and I became inactive.

Over the years, I tried to increase my code speed, but gave up each time after weeks and weeks of practice. In 1987, I practiced daily for about 10 weeks. The theory wasn't a problem, so I passed my Advanced in July. Incentive licensing does work, so I studied code for an entire year and passed my Extra in 1988. I can copy the practice tapes, but I cannot copy CW off air. Most operators seem to send at about 30 to 35 WPM. I might as well try to copy RTTY by ear. I don't even own a key and have yet to make a CW contact. CW is too intimidating for this individual who must have a walnut for a right brain.

Does CW make someone a better operator? Just listen to the antics of the idiots in the pile-ups or the grouches of 75 meters and tell me that knowing CW made them into better Amateurs.

For me, the code requirement is analogous to a fraternity hazing. Forty years is a very long initiation.

Donald J. Sinex, KI6YE,
Huntington Beach, California

A winner!

Dear HR

Many thanks for *The Radio Handbook* by Bill Orr, W6SAI. It was a real surprise to win in the April drawing.

Keep up the good work with the magazine. I have been a subscriber since the very first issue.

Kenneth L. Frank, WB5AKI,
Copperas Cove, Texas

The old man's disease

Dear HR

Its not trying to work 100 countries, or sending out QSLs, or getting QSLs from the bureau. Its not running off at the mouth on 2 meters, or getting on the soap box on 75, and hitting the green keys day and night. Oh, no. We did all of that years ago. But you hear the old-timers say, "Packet radio is not for me. I am too old for that stuff." I can remember that same kind of talk when SSB first came on line.

But, some old-timers are having a ball on packet radio now. They are chasing each other from one BBS to another. You must work DX to do this, and you don't spend your time talking because you have to find the BBS where your buddy left a message for you. Then you send your answer.

I was one of those guys who became "uptight" when I was in a packet connect. Seems there are more BBS mail boxes then mail. So now we can do something we have not done before.

You old has-beens should quit running down packet radio and get with what's here (and not what's coming down the pipe). You are not too old; you are too bullheaded. You don't have to upgrade, just degrade.

W. E. Huffman, KØCVT,
Moravia, Iowa

HF MOBILE ANTENNAS

Methods to help you improve radiation efficiency

By Robert Sherwood, NCØB, Sherwood Engineering Inc., 1268 South Ogden Street, Denver, Colorado 80210

In these days of miniaturization, HF mobile operation is more practical than ever before. Rigs are smaller, and DC inverter power supplies are virtually nonexistent. Are popular, small, antenna resonators a good choice also, or is too much given up in this crictical area?

Background

My early days of low-band HF mobile go back to the early sixties when tube equipment was standard, and there was a mystique surrounding the hardware required to get a station to function from one's car. A typical installation consisted of an AF-67 transmitter with 6146 final, a dynamotor (motor generator) to supply 250 and 650 volts, and a converter to receive 160 meters on a standard AM radio. I noticed that mobile antennas seemed to bring out regional biases — hams running mobile in Northern Ohio favored base-loaded whips as long as possible, while those in the greater Cincinnati area worked the top band with center-loaded whips and capacitive hats.

160-meter whip antenna

Several Cincinnati hams pooled their resoures to create a community mobile of sorts; the equipment, car, and effort were supplied by K8CRJ, K8IBQ, K8RRH, and WA8ADB (now NCØB). Our antenna construction was based initially on a Master Mobile 75-meter 5-foot whip and its matching resonator, which was 6 inches long and 1-3/4 inches in diameter. We discarded this no. 18 wire coil and modified its phenolic insulator to hold a 5-inch diameter plastic tube wound with 100+ feet of no. 16 close-spaced wire to resonate on 160. We added a 6-inch diameter capacitive hat that let us make minor adjustments to the antenna system's resonant frequency. The frequency wasn't easily changed once we had tuned it by removing turns from the coil. No one knew how efficient the antenna actually was, but it performed satisfactorily with daytime groundwave ranges of 50 to 75 miles to a base station.

For the next 20 years, my homemade mobile antennas evolved around variations of this same design. Discussion of HF mobile operation in *The ARRL Antenna Handbook* referred to maintaining the Q of the coil high, so I eventually abandoned the close-wound coil on a solid form. Even though the effect of plastic tubing on Q wasn't known, it was obvious that weather degraded coil operation severely. If the antenna coil got a little wet, the AF67 pi network started tuning backwards. The rig wouldn't load at all in a real downpour. If today's broadband fixed-tuned PAs had existed then, the transmitter would have barely functioned given the slightest bit of inclement weather.

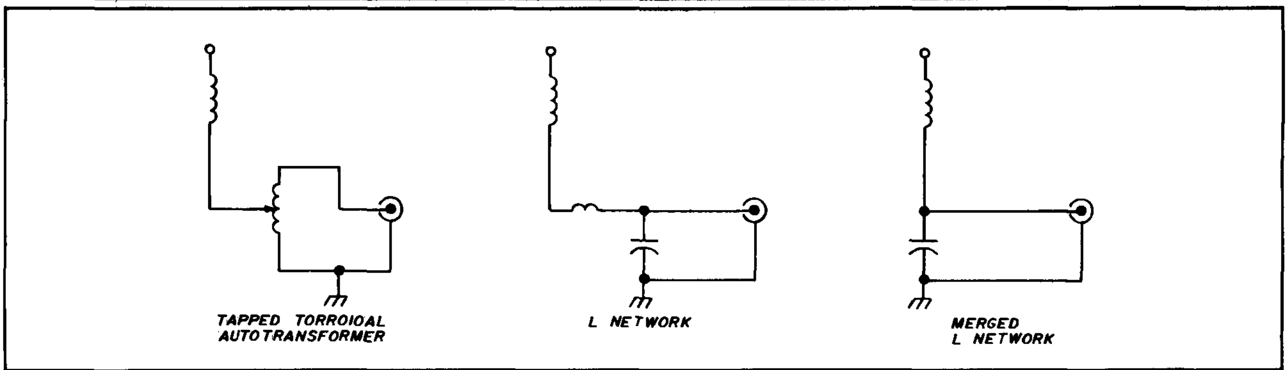
40-meter system

The original Master Mobile insulator was long enough to support half of a B&W 3033 10-inch coil made from six turns per inch of no. 12 wire. Because it was of ribbed construction rather than solid form design, this coil exhibited much less wind resistance than previous units. With a 3 to 6-foot base section and a 5-foot whip, the system resonated without additional top loading on 40 meters. It seemed desirable, however, to continue to use a capacitive hat, since what was advantageous on 160 would be an asset on 40 meters, too. Because my tendency was to assume that bigger was better, I built hats from 12 to 24 inches in diameter. The latter seemed to be the practical limit, especially since the consensus was that a hat should be kept out of the coil field, and that meant mounting it up the whip as much as 2 feet above the coil.

A side benefit of the open-air coil was a virtual lack of environmental effects. Rain didn't detune the coil, and it took a blinding snowstorm to pack it to the point where it wouldn't load.

A 5-foot whip let 5 inches of B&W coil resonate easily on 40 meters, even without a capacitive hat. This meant that I could make two resonators from one coil stock. Since resonance of a short, loaded antenna isn't a 50-ohm impedance, I chose an L network to provide a 50-ohm match. The added coil was simply an extra turn or two in the resonator, with an appropriate capacitor on the high impedance side of the network (across the coax feedpoint). That value was typically 470 pF on 7.2 MHz, 1200 pF on 3.8 MHz, and 2400 pF on 1.8 MHz, depending somewhat on the base

FIGURE 1



Matching options.

section length and mounting position (see Figure 1).

From a mechanical standpoint, this enhanced antenna with its large center loading coil and capacitive hat 2 feet up the whip put quite a physical stress on the bumper or deck mount, so I used a nylon guy line to keep things stable. However, I didn't use springs at the base because they allowed too much lateral sway.

Onward and upward

Once I had a well-developed 40-meter system using 5 inches of coil, I decided it was time to improve my design for 75 and 160 meters. Because 3-inch diameter no. 12 wire coils worked so well on 40, I chose 10 inches for 75 meters. Because it takes four times the inductance to tune a given whip when the frequency is halved, I knew that 10 inches of coil would require a longer whip or top loading. A 2-foot capacitive hat let me tune the antenna with less than 75 μH, even on the low end of the CW band at 3500 kHz. As with the 40-meter resonator, moisture had very little effect on the operation of the coil with six turns per inch spacing.

In 1984, world class mobile DXer KD0U asked if I would make him reproducible 40 and 75-meter resonators. He had 87 countries confirmed and was trying for mobile DXCC. His antenna had to be able to handle a solid-state Metron linear, which produced 600 watts output. Once the project was under way, we were asked by the Dayton Hamvention™ Antenna Forum to present quantitative data on our findings on the 40-meter version in 1985, and the 75 and 160-meter designs in 1986.

Although subjective evaluations of these antenna systems had been acceptable for over 20 years, we needed hard data to truly evaluate what progress had been made toward the goal of transmitting the strongest possible signal on low-band HF mobile.

Comparative and absolute measurements

There are two basic ways to measure antenna performance, comparative and absolute. On 7 MHz, the only method available was the comparative one; I didn't have access to a field-strength meter that would tune that high in frequency. Seventy-five meters was a different case because I could use a broadcast station's field-strength meter to measure absolute signal intensity.

We performed initial 7-MHz measurements in Denver at a large city park with room to make comparisons, using two mobile systems. One mobile was the transmit reference. The other, parked half a mile away, was the receive site. The reference system was a commercial 40-meter antenna with a bumper-mounted 5-foot base section. We tuned it to 7.2 MHz carefully, using a Bird wattmeter. Once it was adjusted for best possible match, we set the forward minus reflected power to 50 watts. We put a resonant antenna on the receiving end tuned for a perfect match at 7.2 MHz. We then inserted a laboratory-grade step attenuator into the receive coax line. Next, we set the received reference carrier from the commercial antenna for exactly S9, substituted a second commercial antenna for the first, and reset the receive S-meter to S9. Surprisingly, there was a difference of only 1/2 dB in favor of the second commercial antenna.

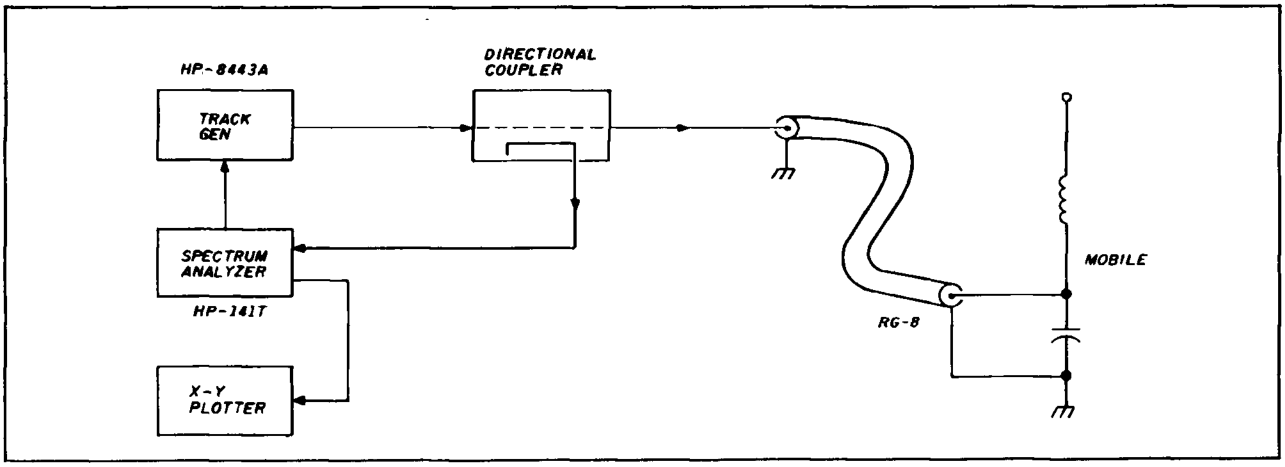
We continued by mounting a homemade antenna (now called the SE-40) in place of the commercial reference, and tuning it to 7.2 MHz. We measured its radiated signal both with and without a 24-inch capacitive hat. Without the hat, the signal registered 5 dB greater than the reference. With the capacitive hat attached and coil requirements reduced by about 40 percent, the signal was 6 dB stronger than the reference. With this much more signal radiated, it wasn't surprising that its coil ran very cool — barely above ambient. We also noted that a 40-percent reduction in coil size (and therefore coil loss) increased the signal only an additional 1 dB.

This implies that ground losses were now predominant in limiting radiation efficiency. We also found that the usable bandwidth of the antenna system with the hat was significantly greater than without; we investigated this later at the lab.

Tests on 3.8 MHz

We moved our testing to 3.8 MHz, again setting up a commercial antenna to radiate a signal with 50 watts of power. We adjusted the received carrier to S9 and recorded the attenuator setting. Then we removed the commercial antenna and substituted a homebrew antenna (SE-75) with 10 inches of open-air coil, a 5-foot whip, and 2-foot diameter capacitive hat mounted 2 feet above the coil. Its measured signal was 4 dB above reference. In this case the hat was necessary to resonate a 5-foot whip with the inductance available. To resonate without a hat required an 8-foot whip,

FIGURE 2



Instrumentation for measuring antenna bandwidth.

which measured 5 dB above reference, but was an impractical mechanical choice. As before, the B&W coil ran near ambient, while the commercial antenna got quite hot after a couple minutes of 50-watt carrier.

We made all tests using the same base section, appropriate coil, and accompanying whip. Additional measurements were later made with K7AYC and NØEYK to determine the effect of increasing base section length. Though it may not be completely obvious, you can change the length below the coil of the center-loaded antenna without changing its resonant frequency significantly. Feed impedance changes somewhat, necessitating a modest change in the shunt capacitor for a 1:1 match, but the length below the coil is rather removed from resonance effects. This is because the reactance of a short whip is very high, and the large inductance needed to cancel this reactance predominates.

We assembled a test setup identical to that used earlier, and repeated our measurements. We varied base section length in increments of 16 inches with both the commercial antenna and open-air coil SE-40 and SE-75. All antennas showed the same 1-dB improvement in radiated signal with a 16-inch increase in base length. Compare this to switching from a 5-foot whip and hat to an 8-foot whip to pick up 1 dB, and it becomes obvious where to add additional length. It was only practical to go to a second 16-inch extension; the system became unwieldy beyond that and would be practical only in a fixed mobile/portable environment. One thing became obvious: a 7-1/2 foot base section, 18-inch 75-meter coil/insulator assembly, and 5-foot whip with 24-inch capacitive hat looks impressive going down the highway! While I've never mobiled using more than a 6-foot base section and the aforementioned antenna assembly, a typical comment at gas stations is: "What you got there, satellite TV?"

Swept VSWR measurements

The next series of measurements we made on our antennas was swept VSWR. Because we're in the filter business, a tracking generator/spectrum analyzer is usual laboratory equipment. By adding a Mini Circuits directional coupler and a length of RG-8, we could run a cable to a parked mobile (see **Figure 2**) and take large amounts of data on antenna bandwidth quickly. We plotted the output with an XY recorder for analysis.

FIGURE 3

RETURN LOSS	VSWR
0dB	∞
6dB	3:1
10dB	1.9:1
14dB	1.5:1
20dB	1.2:1
26dB	1.1:1
32dB	1.05:1
40dB	1.02:1

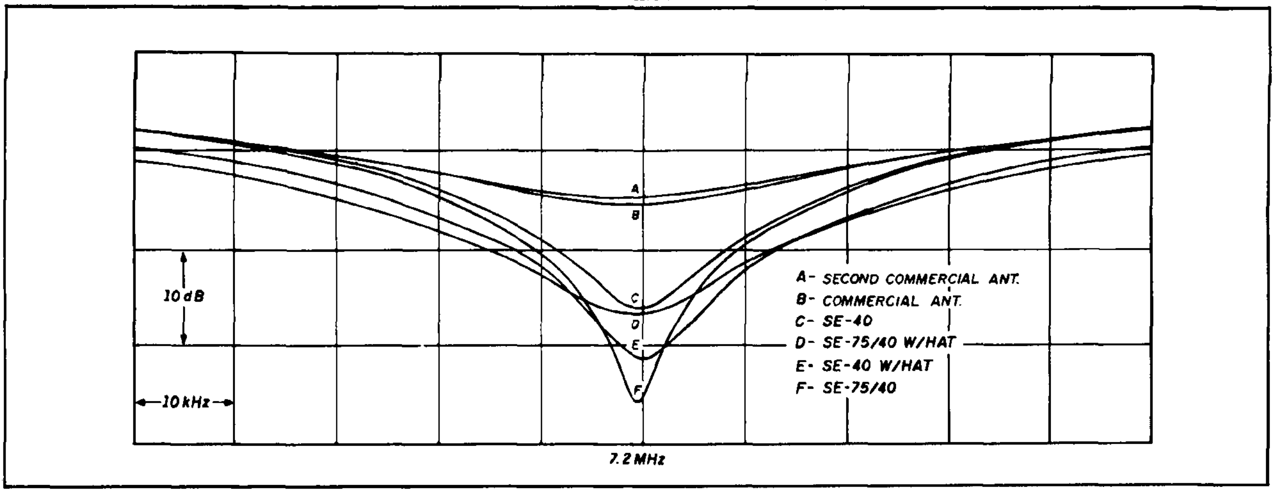
Return loss as a function of VSWR.

With the test equipment set up to measure return loss, we attached a precision 50-ohm termination to the bridge output port, and measured a return loss of over 40 dB. An open circuit set the infinite VSWR reference line, and 25, 75, and 100-ohm terminations were attached to verify operation. All functioned as expected, so we connected the coax from the mobile. We also attached a 50-ohm termination on the car end, and measured over 35-dB return loss. We then attached the antennas, tuned them, and swept them for return loss.

Since the homemade antenna could be adjusted to nearly 1:1 by selecting the base shunt capacitor, it could always be adjusted for 25 to 30-dB return loss. We set the commercial antenna for the best match using its whip length tuning. On 40 meters it could be reduced to just a 15-dB return loss, or 1.4:1 VSWR. The 75-meter match was similar; it reached 14-dB return loss, or 1.5:1 VSWR. Of course you could add a capacitor across the coax with the commercial system, too. When we did this, the best match could be brought down to a 25-dB return loss and a VSWR better than 1.2:1, as shown in **Figure 3**.

After observing bandwidth plots, we noted that the best match at one particular frequency didn't necessarily give the widest bandwidth at a specified VSWR limit of, say, 1.7:1. If you do a lot of frequency changing, you might want to

FIGURE 4



Bandwidth measurements for six antenna configurations.

tune an antenna for the most power output over a measured bandwidth.

When tuned for lowest spot frequency VSWR, an SE-75 system showed a bandwidth of 10 kHz with a 1.7:1 VSWR limit. Retuning for a better average match increased this 1.7:1 bandwidth to 15 kHz, though the match at resonance was worse. The commercial antenna's 1.7:1 bandwidth (without added capacitor) was 7 kHz.

Adding a capacitive hat on an SE-40 also improved the usable bandwidth. There was a typical increase on 40 meters from 50 kHz to 75 kHz at 1.7:1. By comparison, the commercial unit showed about 35-kHz bandwidth. (See Figure 4.)

In 1985, a ham at the Dayton Hamvention™ bought one of these 40-meter antennas, and he and his friend rushed out to the parking lot to compare signals — one with a SE-40 and the other a commercial unit. They happened to have identical rigs, parked about 100 feet apart. About an hour later the gentleman returned to inform me that he and his friend had been on the air getting comparative reports, and the new antenna definitely was running about an S unit stronger.

Additional measurements

We took the next step in the measurement process in 1986 with a field-strength meter. K7AYC and I made measurements in a remote area of Arapahoe County near Denver using increments of 1/4 to 1 mile. With 100 watts of power as reference, we calibrated the field-strength meter and adjusted it for maximum readings at 1/4-mile points. We recorded test data on both 75 and 160 meters because this instrument tuned from 500 kHz to 5 MHz.

We used ground conductivity charts in the *ITT Reference Data for Radio Engineers* to calculate the theoretical groundwave signal for a 1000-watt broadcast station with a quarter-wave antenna and 120 quarter-wave radials. Then we compared this data with actual measurements made on 1600 kHz from a local broadcast station's construction permit proof of performance. Its measured signal strength in mV/meter at 1 mile correlated well with theoretical calculations for average terrain in Colorado. However, unlike the measurements of power and antenna current that a broadcast station makes, field-strength readings are much more variable and inaccurate. We weren't looking for 2-percent accuracy in field-strength values, but a general idea of what level of efficiency was obtainable with an optimized mobile antenna. Field-strength measurements vary with the weather, the season, and the water table. One local station had such difficulty maintaining its pattern that it was forced to move its antenna towers farther away from a grove of cottonwood trees that ran along a creek. The trees' sap content would change periodically and distort the licensed pattern out of FCC specifications. So much for antenna operation being an exactly predictable science!

The ITT book also gives data on groundwave field strengths for different vertical antennas. A quarter wave should give an E-field strength of 186 mV/M over perfectly conducting ground for 1 kW of RF. The correction factor for power is proportional to the square root of power in kW times the 186 mV/M figure. For our 100-watt test level, the correction factor is 3.16 times the measured values.

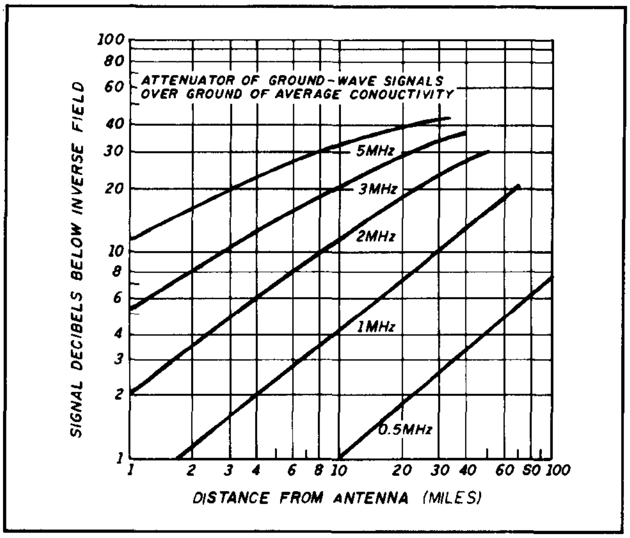
In the real world, with good soil, a value of 165 mV/M is reasonable on the high end of the broadcast band. We also obtained test data from the chief engineer of KRXY, which is licensed on 1600 kHz in Denver, as well as field-strength measurements made by NØSL on a top-loaded 50-foot vertical on 1.8 MHz. Measurements are summarized in **Table 1**.

TABLE 1

Signal strength as a function of frequency.

Frequency (kHz)	Signal strength (mV/M)
Theoretical	186, 1 mile, 1 kW
Typical reference—1600	165, good soil
KRXY—1600	160
NØSL—1800	110
160 mobile—1841	31
Typical reference 3800	112, good soil
75 mobile—3868	66

FIGURE 5



Distance from antenna (meters). (Taken from *Radio Electronic Transmission Fundamentals*, B. Whitefield Griffith, McGraw Hill.)

When you compare E-field values of mobile antennas with reference values obtainable over good soil and a full quarter wave with 120 radials, the figures don't look too bad. Referenced to an antenna over a theoretically perfect conductor, groundwave losses at 2 MHz over good soil are about 2 dB, and approximately 8 dB on 4 MHz due to dielectric losses in the soil. When you compare the mobile signal levels to a fixed antenna over real ground, the 160-meter level is 15 dB down from a full-sized system and the 75-meter level is only 5 dB down (see **Figure 5**).

This means that groundwave range to a good base station is 100 to 125 miles for the prototype 160-meter coil used for these tests, and 200 watts of SSB. Compared with the 50 to 75-mile range of the 50-watt AM mobile mentioned earlier, this is a reasonable range increase. It may be interesting to note that it takes a rather elaborate 2-meter operation to better those ranges — unless your repeater is on a mountaintop.

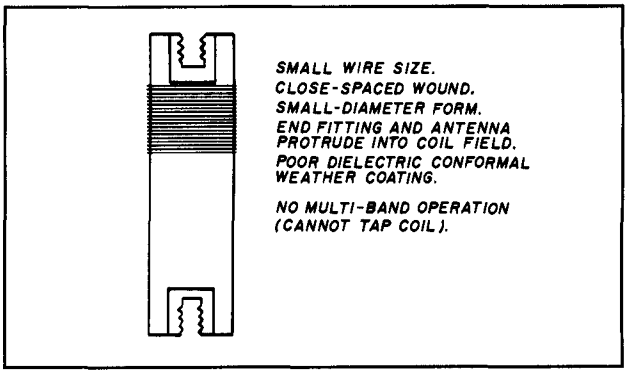
Hardware hints

Here are a few reasons why these lower loss mobile antennas perform better than their smaller counterparts. Coils need to be air wound with only polystyrene ribs for support. Spacing of less than six turns per inch makes the coil susceptible to detuning and degradation from moisture (see **Figures** 6 and 7). Also, when we tried tighter spacing coils on 75 meters to allow a larger inductance and the option of no capacity hat, we noted spurious resonances that fell in the Amateur bands when the coil was tapped down for higher frequencies. While our initial coil support insulators were made from linen phenolic, its high cost and difficult machining problems necessitated a change to Lexan™.

This polycarbonate plastic is stronger, cheaper, and easier to machine. I think it looks better, too. The insulator should be considerably longer than the coil itself to keep the threaded brass inserts out of the coil's immediate field. This will also keep stainless steel antenna parts out of the field. Making frequency adjustment and band changes by shorting out turns with a clip lead may appear to be poor engineering, but so far any attempts at having multiple taps go to a switch have seriously detuned the coil.

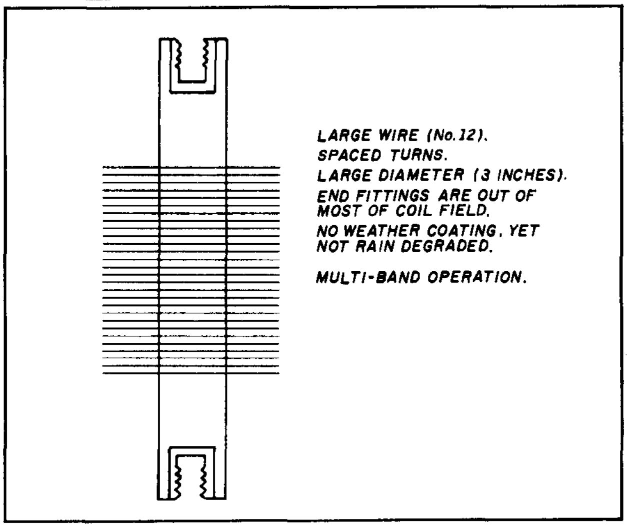
You could argue that 6 dB isn't too much to give up to get the advantage of a small and aesthetically pleasing mobile antenna. Most will find that a signal that's an S-unit stronger often makes the difference between enjoyable mobiling and spending most of the time trying to find someone who can hear you. Add a good RF speech processor and a crisp microphone to this, and the difference is startling. Stations will start calling you! After you've done everything else, couple in a mobile kilowatt linear, and imagine that you're sitting in the passenger seat watching KDØU attack a pileup and come out with a contact and a new country against base station signals. The challenge is there waiting for you. hr

FIGURE 6



Characteristics of low-Q resonator.

FIGURE 7



Antenna High = Q SE-40/SE75 antennas.

KEEPING AN EYE ON YOUR SIDEBAND PEP

By John Fielden, GW4NAH, Penthouse 1, Glyn Garth Court, Glyn Garth, Anglesey, LL59 5PB U.K.

Single sideband is probably the most widely used mode on the Amateur bands today, yet few people can measure their peak output power. The quantity needs to be maximized for best reception at the other end, but at the same time limited to the "linear" capability of the RF power amplifier. Exceeding this may result in distortion, splatter, and license violation.

A modern SSB receiver's S-meter can "hold" signal peaks for comfortable observation, even if it is only of short duration. Unfortunately transmitters have no equivalent, and the only easy recourse for observing peak output on the RF-power/SWR meters that most of us have is to whistle. This is the only noise humans can produce which approaches the sine wave with which our meters are calibrated. This gives acceptable readings on constant power modes (FM, CW, FSK) but is useless and even misleading on SSB, because our whistle is just not that pure.

The error is down to the inability of a moving coil meter, and indeed our eyes, to follow the rapid transients of the voice. The transient voltages are, however, produced accurately by the SWR bridge, so the only modification required is to lengthen the response of the moving coil meter. The add-on module described here performs this function simply and accurately.

Circuit description

In Figure 1, the resistance of RV1+RV2 replaces the meter of an existing VSWR instrument; the voltage developed across these presets is fed via R1/C1 to the noninverting input of operational amplifier (op amp) A1. Its output, appearing at pin 1, charges C3 via CR2 and R6, with a rise time constant of 0.1 second, whereas C3 can discharge only through R7 with a decay time constant of 10 seconds. The voltage across C3 is buffered by voltage follower A2 to pin 7 and via CR3 to the moving coil meter of the existing VSWR instrument, and also via R5 as 100-percent feedback to the inverting input of A1. The total circuit has unity gain, causing the output voltage to rise quickly and exactly to the peak of an input voltage, but then holds the output for a few seconds after the input drops. C2 creates a slight phase advance in the feedback loop to prevent overshoot on rapid transients. The small voltage across CR1 of approximately 0 to 6 volts is used to balance out voltage and current offsets in the op amps via RV3, R3, and R4. The LM358 dual op amp was chosen because it can operate down to zero output on a single DC supply of 4 to 25 volts. CR4 protects against supply reversal and C4 provides a low supply impedance. CR5 and C5 protect the meter from overload and RF, respectively.

Construction

The module can be constructed from readily available components on a small pc board (the commercial version* measures 55 × 30 mm), which can be mounted inside an existing RF-power/VSWR instrument. It may be fixed there with BluTack™ or a bolt, spacer, and nut arrangement, but do so only after calibration. Placement is not critical, except where the SWR instrument is combined with an antenna tuner; in that case the module should be placed away from and shielded from the strong RF fields which exist around tuner coils, capacitors, and their leads.

Interconnections

Undo both leads from the moving coil meter (only from the forward power meter if there are two). Check that the negative lead is grounded; in most instruments it is, but you can find the odd one where the positive lead is grounded, and this has consequences when supplying power to the module. Now ascertain that the meter resistance falls within the range of RV1 + RV2, which is 0 to 2200 ohms. All commercial VSWR meters I have encountered so far do, but some homebrew models using meters with 100 μA or less full scale deflection do not. In that case, make RV2 10 k.

Next, connect the former meter leads to the input terminals of the module and the module's output to the meter, carefully preserving polarities. A DPDT switch or PTT

*The PEP module is available from Technical Software, Fron, Upper LLanwrog, Caernarlon, at 12 pounds, Incl. Vat, P & P. The pc board alone can be ordered from the HAM RADIO Bookstore for $7.00 post paid.

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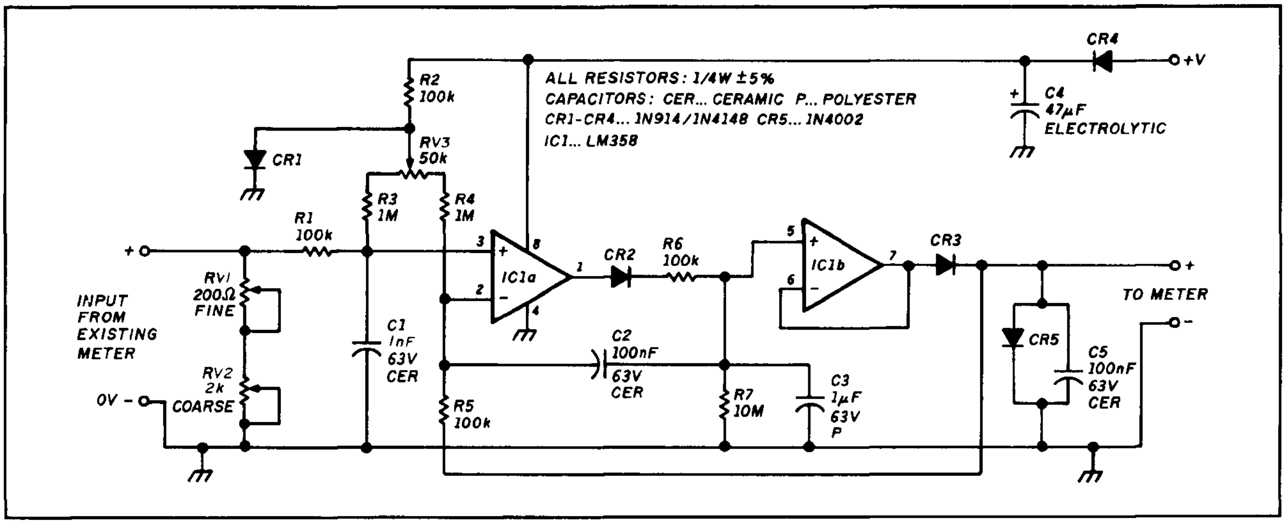
FIGURE 1



Schematic of the PEP measuring add-in circuit.

operated relay can be inserted to switch the PEP module in and out for SSB and other modes, respectively. Another method of reducing the peak holding feature of the module is to reduce R7, say by switching a 220-k resistor across it.

Power, anywhere from 4 to 25 volts DC at little more than 1 mA, must now be connected. If the negative meter lead was found to be grounded, a suitable voltage source, say 9 or 13.8 volts that is "on" when transmitting, can be found on the back of most transceivers. Use a single wire to connect that voltage, preferably through a 2700-ohm current-limiting resistor, to the positive terminal on the module. The coax shield will take care of the negative return.

In the rare case where the positive meter terminal is found to be grounded, a floating power supply must be used. In either case, three Duracell™ pen light cells would typically last nine months if left on continuously, or for years if switched on only when used. In all of the following adjustments, remember that the meter will travel upscale rapidly, but settle back slowly. Do wait for the meter to settle before reading.

First, the op amp offsets must be balanced out. For the commercial module this was done at the factory and RV3 was sealed. If you have built your own, or must replace the LM358 for any reason, a procedure is suggested below. A small positive meter reading with zero input is not an indication of an offset error and upscale readings will be correct.

Next, a calibration level must be established. With the PEP module out of the circuit, your transmitter in a constant carrier mode (CW, FM), and your SWR meter between the transmitter and a dummy load, pass some RF power through the meter. Increase the output to where a stable forward power reading (preferably over half scale) is obtained. Make careful note of the power reading and do not change the transmitter power setting until calibration is complete. Now reconnect the PEP module, set RV1 and RV2 to zero (fully CCW), apply DC power to it, and switch the transmitter back on at the power setting previously established as calibration level. Advance the "fine" preset

PARTS LIST

Capacitors	
C1	1 nF, 63 volts ceramic
C2,C5	100 nF, 63 volts ceramic
C3	1μF, 63 volts polyester
C4	47μF, 16 volts DC electrolytic
Diodes	
CR1-CR4	1N914/1N4148
CR5	1N4002
IC1	LM358
Resistors	
R1,R2,R5,R6	100 k, 5 percent, 1/4 watt
R3,R4	1 meg, 5 percent, 1/4 watt
R7	10 meg, 5 percent, 1/4 watt
RV1	200 ohm Mouser Electronics Part no. 32RH202
RV2	2 k Mouser Electronics Part no. 32RH302
RV3	50 k Mouser Electronics Part no. 32RH405

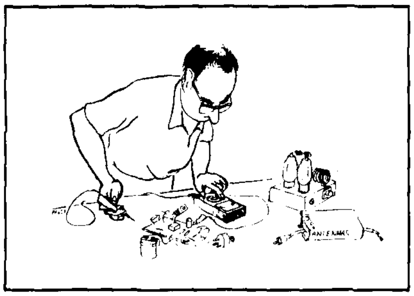
RV1. If, with RV1, you can exceed the calibration reading previously noted, adjust to this reading. If the meter does not rise far enough upscale, set RV1 to about mid-travel and slowly advance the "course" preset to the calibration reading. RV1 will now allow more precise adjustment.

This calibration makes sure that RV1+RV2 presents the same load to the SWR instrument as the moving coil instrument previously did, so the input voltage to the module is unchanged. The module has exactly unity gain, so this voltage is repeated at the output, i.e., across the meter. Consequently the original meter calibration, nonlinearities and all, remains unchanged. On fast peaks, however, such as are encountered when speaking on SSB, the module will hold a peak long enough for the meter to rise to it and for you to check it.

Results

The results will probably surprise you. Without the module, normal speech will show peak meter readings of, say 30 percent of what an oscilloscope would indicate. With the module, it's 100 percent. A whistle, without the module, will show 80 or 90 percent, not 100 percent. Another interesting example is produced by tapping the mic with a pencil. The unmodified meter will show no reading, but with the module, full power will be indicated.

Ham Radio Techniques



Bill Orr, W6SAI

THE LOG PERIODIC ANTENNA FAMILY

Bill Orr, W6SAI

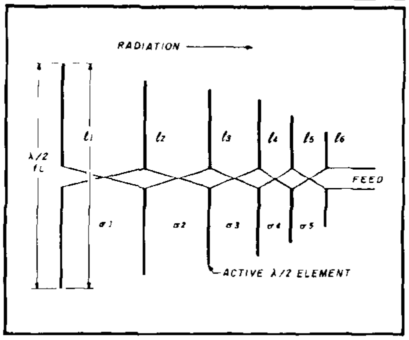
In 1957, D. E. Isbell and R. H. DuHamel published papers on the design of log periodic (LP) antennas.[1,2] There was a flurry of interest among Radio Amateurs, who adapted some interesting VHF LP antennas from the original design. But it wasn't until 1973, when the log periodic dipole (LPD) array was published by P. D. Rhodes,[3] that this class of antenna became practical for HF Amateur use.

Now that two new ham bands are available at 18 and 24 MHz, interest in the log periodic antenna is growing. How else can an active Amateur cover five bands? (How about a center-fed Zepp? — NX1G). The log periodic antenna's principal virtue is that it can cover a frequency span of 2:1, or more, while maintaining good power gain and front-to-back ratio over the whole range.

The log periodic dipole beam shown in **Figure 1** is a popular configuration for VHF television antennas. It's also used on the VHF/UHF ham bands. The pattern is directed toward the apex. The bandwidth of operation can be roughly defined as the frequencies at which the outer dipole elements are about one-half wavelength long. The element lengths and the relative spacing δ are arranged in a geometric progression with a taper factor τ.

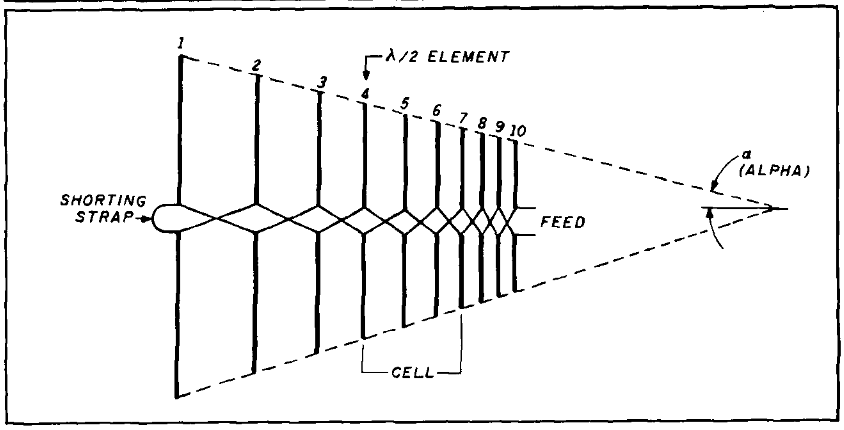
The dipoles are fed at their centers from a parallel wire transmission line transposed in such a way that successive dipoles are 180 degrees out of phase. A broadband structure is formed, with most of the radiation coming from those elements which are about a half wavelength long at the operating frequency. In a ten-element log periodic antenna that covers a 2:1 frequency span; perhaps only four of the ten elements are active at a given frequency within the operating range (see **Figure 2**). The shorter than resonance elements tend to act as directors and the longer than resonance elements as reflectors. The current distribution in the structure is such that only a "cell" (active region) of elements is active on a given frequency. The cell of active elements moves back and forth along the array as the operating frequency is changed. The gain and bandwidth thus bear a definite relationship to the length and included angle of the structure. The smaller the

FIGURE 1



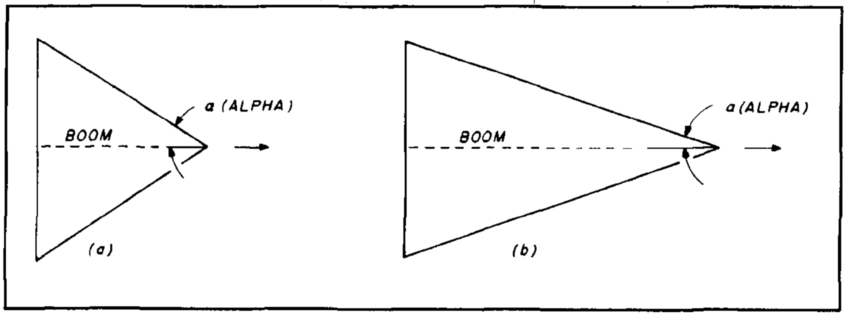
A six-element LPD beam. Element spacing (δ) and element length (λ) are determined by design factors, the longest element (λ) being about a half wavelength at the lowest operating frequency (fl).

FIGURE 2



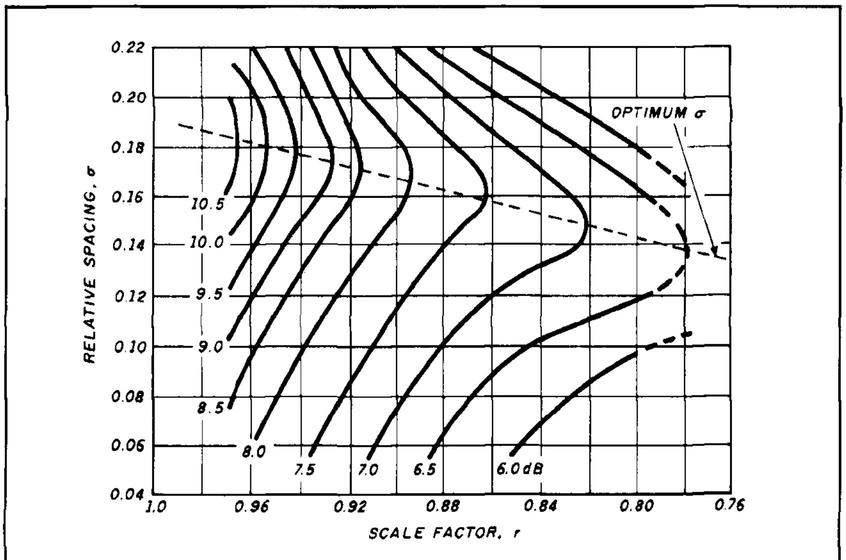
Log periodic active region (cell) encompasses elements a half wave long and a few shorter elements. Other elements have small induced currents and are not major contributors to the radiated energy. Shorting strap on longest element improves front-to-back ratio.

FIGURE 3



Increase in boom length and decrease in apex angle (α) *mean more elements in a cell and increased gain. A greater frequency span also requires a longer boom (B). High gain on a short boom (A) restricts frequency span.*

FIGURE 4



Reproduction of graph showing corrected gain figures for LPD array. Graph is in *Antenna Engineering Handbook, Johnson and Jasik, First Edition, pages 14-28. (Illustration courtesy Gary Breed, K9AY, Editor, RF Design magazine.)*

included angle the more elements in a cell, the longer the antenna, and the higher the power gain. (See **Figure** 3.)

The HF log periodic dipole antenna

Antenna boom length is of secondary importance in the VHF region, where a high gain, wide bandwidth log periodic array can be constructed on a boom about one or two wavelengths long. But because of the large size of the antenna, things begin to get out of hand quickly when you consider HF operation.

LPD array gain can be expressed in terms of the number of elements in the cell, the relative element spacing, and the scaling factor used. In general, power gains from 5.5 to 10.5 dBi (3.36 to 8.36 dBd) are the minimum and maximum gain limits of practical HF log periodic designs. (The larger arrays produce the higher gain figures.)

A representation of LPD antenna gain is expressed in Figure 4, Chapter 10 of *The ARRL Antenna Book*.[4] This chart was extracted from an early work of Carrel,[5] which was later found to provide inaccurate directive gain computations.[6] My **Figure** 4 shows a corrected graph.

High gain LPD arrays are defined in the relative spacing region of 0.12 to 0.22 and large values of scaling factor (0.98 to 0.92). Unfortunately, these figures produce large array sizes that are almost impossible to achieve in an Amateur HF installation. One look at an HF LPD array at a military base quickly disproves the idea that a block-buster LPD rotary antenna can be placed in a typical backyard!

Practical HF LPD beams

However, all is not lost if those of us who use wideband LPD arrays are content to settle for a modest gain figure, while still retaining good front-to-back ratio and reasonable boom length. Ace Collins, K6VV, has described three LPD arrays (summarized in Table 1). These arrays can be built on boom lengths that approximate a single band Yagi beam.[7]

ATN Antennas of Birchip, Australia makes two commercial LPD beams that cover 13 to 30 MHz.* One design is on a 28-foot boom and has eight elements; another design covers the same range and has six elements on a 20-foot boom. The DJ2UT multiband antenna, built on a 20-foot boom, is a variation of the LPD design that covers 13 to 30 MHz.**

The ARRL Antenna Book (pages 10-5 and 10-6) describes a very small LPD design with a 10-foot boom that covers 18.06 to 29.7 MHz. It has just five elements and (according to the graph in **Figure** 4) provides only 3.2-dB gain over a dipole. It's doubtful that placing this amount of aluminum up in the air is worth the unspectacular power gain.

LPD power gain

You can compute the power gain of a LPD antenna from the design formulas and **Figure** 4. This figure can be expressed in terms of boom length for Amateur use in the HF region — much in the way it's done for conventional Yagi antennas. When compared on a band-by-band basis with a Yagi, the tradeoff of gain for bandwidth becomes apparent. For example, a three-element Yagi for 14 MHz provides about 6.5-dBd gain and is built on a 17-foot boom. At that boom length a typical 14 to 30-MHz LPD provides 3.5-dBd gain. The Yagi wins by 3 dB!

At 28 MHz, you can build an eight-element Yagi on a 45-foot boom which will provide nearly 10-dBd gain. An equivalent LPD on that boom provides only 7-dBd gain. The long Yagi wins by 3 dB.

* ATN Antennas, 56 Campbell Street, Birchip 3486, Australia.
** Sommer GMBH, Kandelstrasse 35, D-7809 Denzlingen, F.R.G. Sommer Antennas, W4/DJ2UT, PO Box 847, Cowpens, SC 29330.

TABLE 1

Three LPY designs by K6VV (*QST*, November 1988). Shorting strap on longest element is 8″ long. Average feedpoint impedance is 64 ohms. Design constant (τ) = 0.9, spacing constant (δ) = 0.05, average gain (from Figure 4) = 4.61 dBd.

	11-element array 13.5—30 MHz Boom = 25 feet		9-element array 17.5—30 MHz Boom = 16 feet		7-element array 20—30 MHz Boom = 12 feet	
Element number	Length feet	Spacing feet	Length feet	Spacing feet	Length feet	Spacing feet
1	36.44	3.64	28.94	2.78	24.53	2.45
2	32.80	3.28	26.05	2.50	22.08	2.21
3	29.52	2.95	23.44	2.25	19.87	1.99
4	26.57	2.66	21.10	2.03	17.89	1.79
5	23.91	2.39	19.00	1.82	16.10	1.61
6	21.52	2.15	17.09	1.64	14.49	1.45
7	19.37	1.94	15.38	1.48	13.04	-
8	17.43	1.74	13.84	1.33	-	-
9	15.69	1.57	12.46	-	-	-
10	14.12	1.41	-	-	-	-
11	12.71	-	-	-	-	-

The LPD array swaps bandwidth for power gain at any frequency, when compared with a Yagi of equivalent boom length. While the power gain figures of both types of antennas are approximate, the examples shown are indicative of the relative gain performance of these interesting antennas.

The LPD antenna has a couple of advantages. First, it allows a solid-state transmitter to operate efficiently over a wide frequency range without an antenna tuner. Second, it maintains its front-to-back characteristics over the complete operating range — something many Yagi designs can't do.

Is the tradeoff of power gain for bandwidth worth it? You'll have to answer that question yourself.

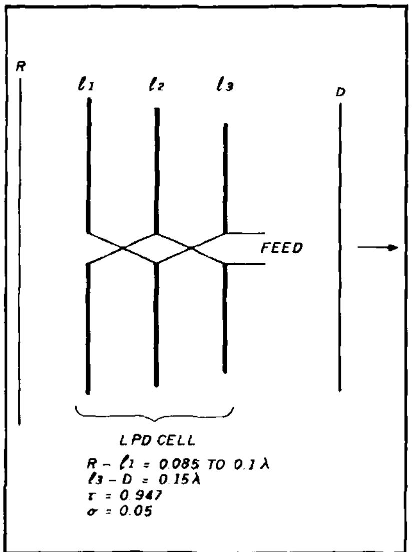
The log periodic Yagi (LPY) array

Peter Rhodes, K4EWG, and J. R. Painter, W4BBP, have described an interesting hybrid antenna.[8] It's designed for single band use, and combines an LPD cell with parasitic elements. The designers claim this configuration achieves higher gain and greater directivity over a single Amateur band than either an LPD or a Yagi array alone (see **Figure 5**). Best of all, these attributes are achieved with a boom comparable in length to that of a small Yagi. They claim a gain figure of 11.5 dBd for a 14-MHz LPY with a boom length of 26.5 feet. A four-element Yagi on the same boom would provide about 7.3-dBd gain. This gives an apparent signal advantage of about 4 dB for the LPY array over the Yagi. It sounds almost too good to be true!

The log periodic cell in the K4EWG/W4BBP LPY is designed for a single Amateur band, rather than a wide range of frequencies. A three-element log periodic cell provides a power gain of about 3 to 4 dBd over the design range. According to Leo Johnson, W3EB, adding a single reflector and a director provides another 4.5 dB.[9] If the gain figures are added, the resulting overall gain for the array is about 8.5 dBd. A second director boosts the gain an additional 1.5 dB, for a grand total of 10 dBd.

This agrees roughly with the gain figure proposed by K4EWB. Personally, I can't verify the gain of an LPY antenna. I know of no computer program that considers this antenna type and I'll reserve my judgment until somebody comes up with one. (I look forward to hearing from a programmer who can combine the virtues of the Yagi with the LP cell in one program and arrive at meaningful results.)

FIGURE 5



The log periodic Yagi design of K4EWG and W4BBP. Parasitic reflector and director(s) boost gain of LPY cell and improve front-to-back ratio.

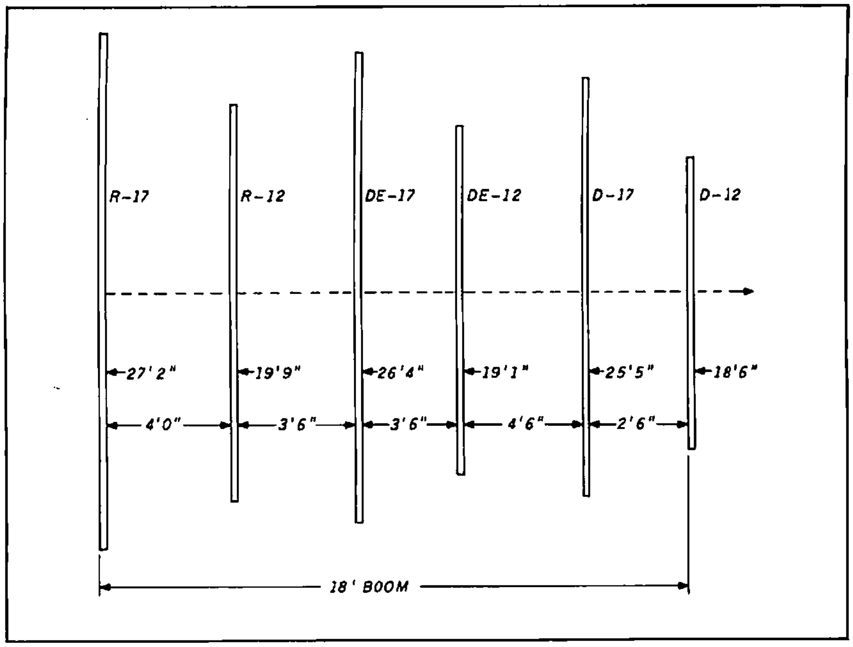
I must admit the LPY concept is tempting. I know that Burt, KV4AD, has a W3EB-type LPY beam on 12 meters, and I have heard his rock-crushing signal. **Photo A** shows a seven-element 10 to 30 MHz LP4 antenna. Perhaps I'll build one of these antennas and try it out on 10 meters. There's no substitute for experience!

A two band Yagi for 18/24 MHz

Brad Butcher, W9WPV, designed and built a two-band, interlaced, three-element array for 18 and 24 MHz. It's shown in **Figure 6**. The beams are built on an 18-foot boom and fed with separate gamma matches and coax lines. The SWR on each band is about 1.1:1; the front-to-back ratio on either band is better than 20 dB. You make your band selection at the operating position with a coax switch. This array, plus a conventional tribander, can provide coverage of the five popular HF bands with a minimum of fuss.

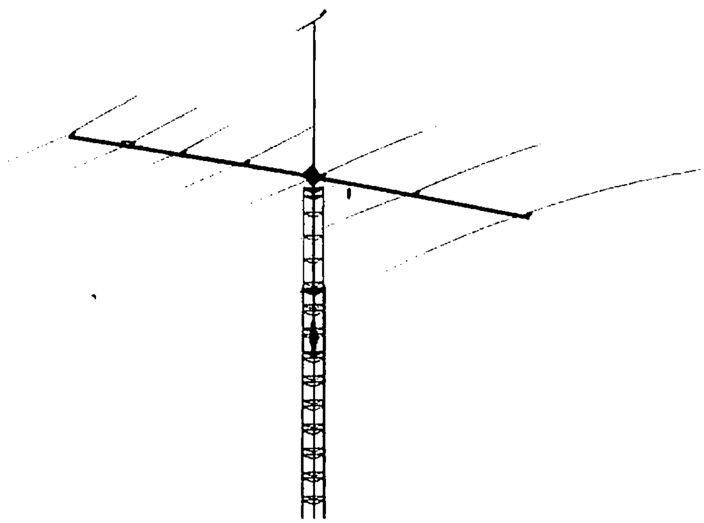
Did I hear someone ask about stacking this beam over a tribander on one tower? If I were to do this, I'd want at least 6 feet — and preferably 10 — between the antennas. Maybe some-

FIGURE 6



Dual Band (17/12 meter) beam of W9WPV. See August column for gamma match data. 17-meter gamma approximately 2'6" long. 12-meter gamma approximately 2'0" long.

PHOTO A



Seven-element LPY beam on 30-foot boom covers 10 to 30 MHz. Six-element cell plus director provides good gain and F/B ratio. Longest element is 42'9"; shortest element is 12'6". Director is 13'6-1/2". (Type KLM-10-30-7LP.)

one will try a stacking experiment to see how it works out!

The Dead Band Quiz

What with all the ionospheric fade-outs, solar storms, and summer lull in DX, there should have been plenty of time to solve the latest quizes. Many thanks to those who have written to me. I appreciate your comments and regret that I don't have the time to write and thank you all individually. I also appreciate your suggestions for future topics in this column!

The March quiz (the "black box") has several solutions. The simplest is a "star" of five 0.5-ohm resistors. Jack Cleary, N2JHS, and Curt Anderson, K3GCM, found this solution. Ed Clegg, W3LOY, pointed out that a "pentagon" of 1.25-ohm resistors would also do the job.

The April quiz dealing with coax lines was quickly solved by W9BTI, WB4HXE, W5DS, KC2KB, N3GDE, W2RJW, W4EIN, K7FC, W7FSP, KJ6GR, VE4KZ, WB6BYU, and WX4D. They knew that the impedance between the shields was zero. Replies are still coming in. I'll try to list them in my next column.

Thanks to all and 73! hr

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PROTECT YOUR AMATEUR STATION FROM LIGHTNING

By Richard Little, KY9L, Cellular Systems Group, Motorola, Inc., 1501 West Shure Drive, Arlington Heights, Illinois 60004

More lightning damage occurs to electronic equipment than is generally realized, because much of it is manifested in post-stress failures weeks or months after the damaging surge. Even if you have lightning insurance, these kinds of failures are rarely covered, nor is the lost time and aggravation. Surge damage is real, but it doesn't need to happen.

Most books and articles on the subject of lightning protection recommend extensive arbitrary cross bonding of grounds — often in ways that increase the flow of surge current through the equipment. I take exception to these practices. Thorough study of the problem as it relates to Amateur Radio shows that:

- Most Amateurs cannot afford the kind of installation that would permit them to operate safely with outside antennas during a thunderstorm.
- It is practical to ground an Amateur station in a way that can completely eliminate direct surging of the equipment while the shack is shut down.
- The techniques for eliminating surges during shutdown are consistent with providing at least modest protection if the operator is caught unaware of an impending storm.

I'd like to share some information on an improved method of lightning control that can eliminate damage while your station is shut down and provide some degree of protection if lightning strikes when you're operating.

Do you carry lightning insurance on your ham equipment? Does it cover the decrease in reliability that so often follows a lightning strike? It would be better if your equipment never receives this kind of exposure. But short of packing the equipment back in its shipping containers every time you leave the shack, what are your alternatives?

When the static charge at the base of a cloud builds up to around a hundred million volts, it can jump ("step" is a better word) 150 feet or so as a small arc toward a pocket of opposite charge in the surrounding atmosphere. Within about 50 μs it may step again and again, extending the small arc farther and farther along the previously ionized trail. If such an arc ultimately establishes itself to something on the ground, a massive surge of current will rush through the ionized path to neutralize the charge. The extremely high voltage forces the surge of current to rise to a peak value of 10 to 100 kA in 0.1 to 10 μs. It then decays to half crest in 20 to 200 μs. Most strokes consist of several of these surges, each neutralizing more and more of the cloud, but the first one is the largest and the one that usually damages electronic equipment. The fast leading edge (20 kA/μs typical, with 1 percent exceeding 100 kA/μs) can result in the top of a tower momentarily "jumping" a million volts with respect to its base. This is why lightning has no problem jumping across switch contacts and guy wire insulators, or even right through the wall of a house from an ungrounded exterior coax.

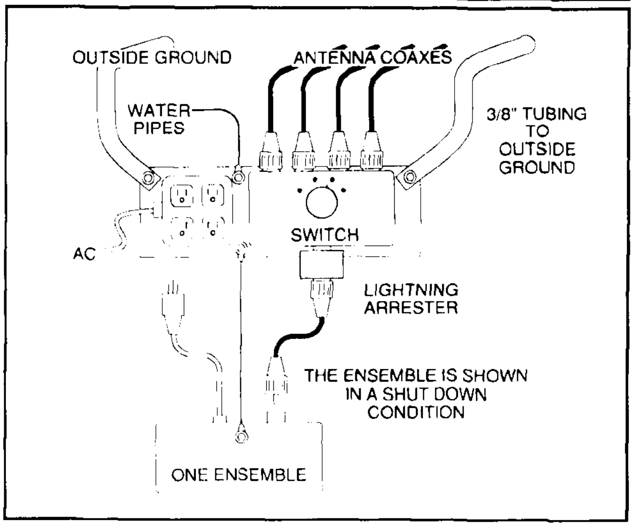
What kinds of protection?

Personal safety is your first concern. This means tying all grounded objects together to prevent side flashing between them, and perhaps augmenting the ground. Secondly, Amateur antennas expose our homes to more and larger surges so you may wish to add some protection to your more expensive non-Amateur equipment like stereos, TVs and VCRs, and home computers. You can provide excellent shutdown protection for your Amateur equipment and perhaps, depending on your pocketbook, some tolerance should you not shut down in time.

For safety of people!

I'm often asked if the antenna grounding should be kept separate from the house ground. Absolutely not! **I strongly encourage integrating everything into a common ground.** I don't think any lightning professional would disagree. The same reasoning is behind universal building codes which tie electrical ground, phone line protector ground, water pipes, and TV cable together. While bond-

FIGURE 1



Installation showing the station (ensemble) in a shutdown condition. All grounds are located at a small ground window.

ing them together may increase electrical surging in the house should the antenna get hit, it also makes the surge path more predictable. Everything moves (electrically) more or less together, proving safer for people as well as your equipment. This ground should include:

- Outside ground, made up of:
  1. Tower ground (including guy anchors)
  2. Radials
  3. Ground stakes (several recommended)
  4. Step voltage protection (if used)
  5. Chain link fence (if within 20 feet of other grounds)
  6. Rain gutters
  7. Well casing
  8. Connections to inside ground (at least two recommended)
- Inside ground, made up of:
  1. Water pipes, power ground, cable TV feed and phone line protector. (These should already be integrated, but if not, DO IT! Cross bond if in doubt!)
  2. Duct work
  3. Structural (like basement I beams)
  4. Shack ground, including:
     a. connections to outside ground
     b. coaxes where they enter the shack
     c. open wire feedline shorting switch (if required)
     d. grounds of each of the power outlets feeding the equipment
     e. rotor control box (otherwise provide with a three-wire cord)
     f. all equipment that is provided with ground lugs
     g. equipment desk (if metal)

I'll discuss the shack ground in more detail later.

Protecting non-Amateur equipment

Use three-way surge-protected power strips for any expensive electronic equipment; those strips housed in metal cases are more convenient for making auxiliary ground connections. Plug the TV, VCR, and all video accessories into a common strip and ground the braid of the coax feed to that strip using a short bonding strap. For a home computer, plug the computer and **all** of its peripherals into a common strip. If your system incorporates a phone line modem, acquire a secondary phone line protector and ground it directly to that strip with a short bonding strap.

Shutdown protection: surge isolation

For simple shutdown protection, pick a central point where it's convenient to bond all of the shack ground items listed — including all the antenna coax braids — and call that point "shack ground." If you arrange these connections into a neat, small, "ground window" (see **Figure 1**), you will also have a degree of surge attenuation. In any case, the antennas, rotor, and other equipment each bear separate consideration.

Equipment grounds

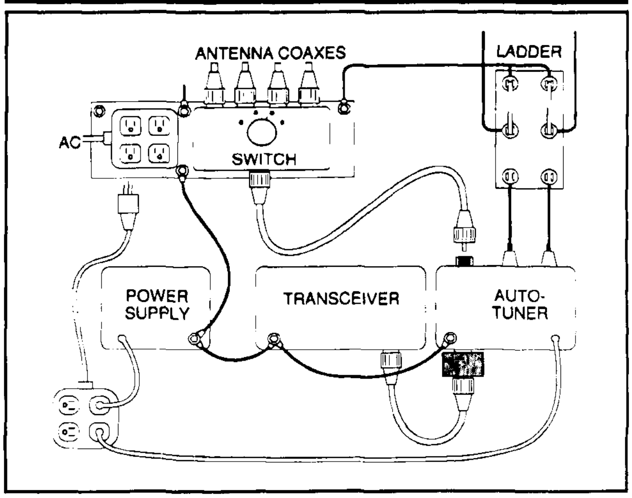
You can organize your shack into one or more equipment ensembles, each having just one connection to shack ground in addition to antenna(s) and power cord(s). **Figure 2** shows an example of a grouping with one connection to the shack ground. Most of you will prefer a single ensemble in which all of the equipment grounds are connected to a steel desk or a "bus bar," or otherwise cross bonded to one another and then grounded to shack ground *via a single wire*. Of course, a tuner that's being treated as "antenna," as depicted in **Figure 3**, must not be in conductive contact with any of the equipment of an ensemble (except via common shack ground when shut down, or coax when not shut down).

Connections between different ensembles are not permitted. If a power supply, a speaker, a microphone console, a keyer, or a computer interface connects to more than one transceiver, they must all be part of the same ensemble. One word of caution: A more elaborate ensemble tends to be less surge tolerant. Each ensemble may incorporate its own multiple outlet power strip, which simplifies shut down.

Antenna grounding and switching

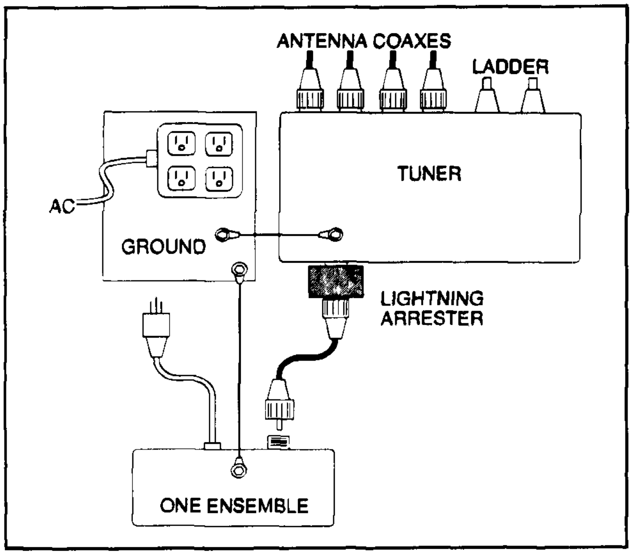
Bond the shields of all antenna coaxes to shack ground. A properly grounded coaxial switch will work. Including the antenna switches and/or the tuner as part of the antennas (as shown in **Figure 3**) minimizes the number of discon-

FIGURE 2



An ensemble using only one connection to the ground window.

FIGURE 3



Antenna tuner is treated like an antenna and must be isolated from the rest of the ensemble, except for the common ground.

nects required during shutdown. This also cuts down on HF "RF in the shack," particularly if the antenna isn't truly balanced or isolated by a feedline choke.

Tuners, built in transceivers, and autotuners are treated as part of an ensemble, as shown in **Figure 2**. In these cases, if any of your antennas are not well balanced or isolated, reduce RF in the shack by defining the shack ground as close as practical behind the ensemble to minimize the length of the single wire between the ensemble (preferably the tuner) and shack ground. Counterpoise wires must attach to shack ground, not directly to the ensemble.

Make sure antenna switches are the grounding type and able to ground all antennas at shutdown. Use a DPDT knife switch to disconnect *and ground* a ladder line if you use one. A remote coax switch that uses a separate control cable is best treated as a "rotor controller." Those switches using the coax for control and power are best treated as "equipment," thus the antenna coax will be disconnected and its center conductor grounded during shut down.

Rotor controller

The rotor can't avoid surging; neither can the controller, unless the rotor cable is disconnected and all its wires are grounded at shut down. Short of that, the rotor and its controller have an intrinsic degree of surge tolerance that the following procedure neither helps nor harms. You can modify them to improve this tolerance, but these modifications are beyond the scope of this article. However, to protect the rest of your equipment, and for your own safety:

- If it has a two-wire power cord, ground the controller to shack ground and pull the plug when you shut down.
- If it has a three-wire power cord, surge protect your grounded outlet box, and leave the rotor controller plugged in at all times.

Shutdown performance

This is a rudimentary ground scheme; it provides excellent surge isolation when shut down, but only modest surge attenuation otherwise. To shut down:

- Unscrew the antenna coaxes where they enter each equipment ensemble. Switches are unacceptable for this purpose.
- Pull the power plugs that feed each equipment ensemble from the shack-grounded outlet box. Again, switches are unacceptable.
- Ground the antennas, including all the center conductors.
- Disconnect the phone line from a phone patch or from a computer/modem that's part of an ensemble.

Check *your* work! *There should now be but one ground* path from each ensemble to shack ground.

Improving surge attenuation

Few of us can afford the full surge protection that would permit us to operate with impunity during any storm. Surge damage to equipment can occur in the following ways:

Coax differential voltage. The surge generates a difference in potential between the sheath and center conductor. This can damage a receiver, a transmitter, or just the coax.

Coax chassis surging. The sheath "whiplashes" the entire rig with respect to its other external connections like keyers, computer interfaces, phone patches, shared speakers, and microphone consoles, damaging the interfacing circuitry in either the rig or a peripheral, or both.

Coax chassis ground surging. The surge enters via the coax and leaves via either power or ground, causing destructive internal voltages in the equipment.

Power surging. A surge injected by an antenna stroke generates a large electric transient between AC hot, AC common, and/or the power panel *ground*. The three-way protector minimizes this.

Telephone line surging. A surge injected by an antenna stroke generates large voltage spikes on the equipment with respect to the telephone lines. A secondary phone line protector minimizes this.

The damage may be apparent immediately, or randomly after the fact. It could show up hours, days, or months later. Often a "zapped" rig exhibits poor reliability forever after.

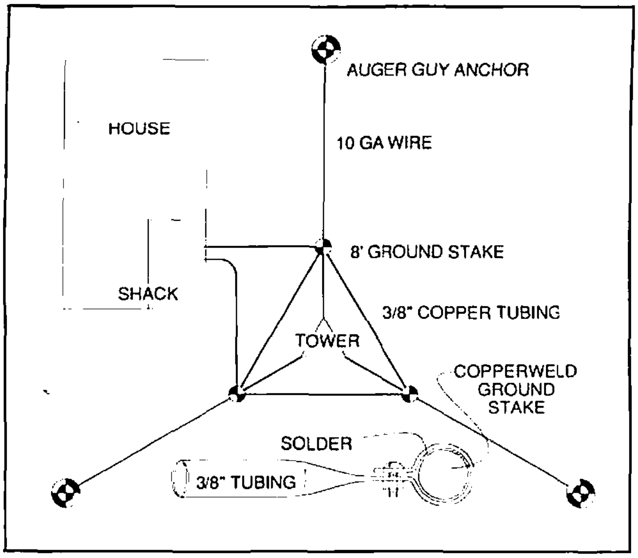
For surge attentuation, the first prerequisite is three-way surge protection on the AC outlet boxes, secondary telephone line protectors grounded at those outlet boxes, and coax arresters between the antennas and the equipment ensembles. After that, the protection depends upon:

- The magnitude of the stroke.
- How well shack ground is developed into a small ground window — including the lengths of the coax sheath bonds and the AC outlet box bond. Short is important! Fat (wide) also helps. This is because lightning propagates like RF — on the surface of a conductor more than within the conductor, i.e., skin effect.
- The quality of the outside ground.
- How well the coax sheaths are grounded at the tower base, thus diverting sheath surge current into outside ground.
- The surge tolerance of the specific radio equipment.

The inside ground

Figure 1 shows how I have developed a *small* ground window at a point directly behind my operating desk. Commercial installations often provide a heavy copper plate for mounting the surge-protected power panel, the phone line protectors, and the coax terminators/arresters. A very low

FIGURE 4



Layout of a "good" outdoor grounding system.

inductance between these items and careful ensemble isolation (except at the window) are essential for good surge attenuation.

I've also cross bonded my water pipes, gas pipe, conduit, boiler, and water heater extensively, using heavy braid (sheath from scraps of RG-8/U) and stainless hose clamps, which may help reduce intermodulation TVI. The conduit that feeds the shack has braid jumpers across all of its joints and to the power panel.

Outside ground

In commercial work we use no. 2 gauge wire (no strands smaller than no. 17 gauge) for any conductor that must carry full strike current without vaporizing, and no. 6 gauge for miscellaneous grounds like rain gutters and chain link fence. At home I use 3/8" copper tubing between the tower legs and each of three ground stakes, between the stakes, and to inside ground (see Figure 4). I flatten the ends and either drill for bolts, or wrap around a stake and drill, bolt, and solder as in Figure 4. My stakes are 8 feet long, 10 feet apart, and at least 6 feet from the house. They are driven so the tops are a foot below grade; the tubing is also about a foot deep. In addition, my guy anchors, well casing, and power ground augment my shack ground.

Experts recommend you put a no. 2 gauge perimeter wire around the house below the frost line several feet from the house, with ground stakes at the corners. This is primarily to equalize the slab step voltage, but it also augments outside ground. Without this wire around the foundation, any equipment (including insulated cables or a steel desk) within several inches of the slab may side flash to it. Use a wood desk on a slab and keep the cables off the floor!

Experts also bury a grid of no. 6 gauge wires below places where people might walk during a storm. Without this grid, a stroke could produce a "step voltage" gradient in the ground such that the surge current would prefer to take a path through a body — from one foot to the other. Unless you have a fully developed outside ground, stay away from it during storms!

Setting priorities

Your first priority is people protection. This means using increased grounding and taking care to ensure a good, well-integrated ground system. Next, you'll want to provide surge protection on the AC power lines of your expensive electric equipment so you needn't suffer the aggravation that follows surge damage. You'll want to hook up your Amateur gear in such a way that it's immune from surging if properly shut down. You may wish to provide a degree of surge attenuation for your radio equipment in case you are caught unaware of an approaching storm. This, in large measure, will depend on circumstance and, perhaps, your pocketbook. You can obtain the most protection for your money by adding a small ground window in your shack, combined with a modest outside ground. Thereafter, augmenting the outside ground will add still more improvement.

I hope the information I've presented here starts you off in the right direction. Check the bibliography at the end of the article for valuable source material. hr

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Finding the source of computer-generated interference

Using a computer system near an Amateur Radio receiver (operating a packet radio station, for example) is likely to cause receiver interference. To pinpoint the source of the interference, go through this quick check list while listening to the noise in the receiver:

1. Disk drive: Does the noise appear only when the disk drive is transferring data? Does the noise disappear when the drive is turned off? Does the noise change in intensity when you move the drive cables?
2. Monitor: Does the noise stop when the monitor is turned off? Does the noise stop if you move the cables?
3. Printer: Does the interference occur only when the printer is running a print job, and stop when the printer is turned off?
4. TNC: Does disconnecting the audio cable solve the problem? Does turning off the TNC solve it?
5. Computer: Does turning off only the computer remove the interference?

If this procedure fails to find your culprit, tune a portable AM radio to an unused portion of the band and use it to sniff out the source of the problem. You'll probably be surprised at the variety of different computer-generated noises the receiver picks up. Concentrate on the type of noise affecting your radio receiver and ignore the rest, since it's not impairing your reception. Move the AM receiver near cables, power cords, and disk drives to find out where the noise originates.

I used this technique and found that my interference problem occurred only when my Commodore 64 was on. The interference was in the form of RF coming from the computer itself. I wrapped a piece of brass window screen and cardboard insulation around the motherboard and soldered the screen to a ground connection. This solved the problem completely and took only about an hour to do.

Dean F. Poeth II, K8TM

HOMEBREW DIPLEXER

There are now several good dual band (144/430 MHz) antennas available. Unfortunately, many of the dual band rigs have separate antenna input sockets for each band. How do you cope with the problem of getting one plug into two sockets? The answer is a simple bit of circuitry called a diplexer. This device sorts out the various frequencies and routes them to the appropriate rig. They are available commercially at a rather high price. But those that I have measured, while safe to use, don't show up too well on separation and also tend to have an unacceptable loss when placed in circuit.

The circuit

The circuit of a homemade diplexer, which is well within the construction capabilities of the newcomer to homebrewing, is shown in **Figure 1**. It consists of three coaxial sockets and four series-resonant circuits. I hope you'll remember that a series-resonant circuit has a very low impedance at resonance and a high impedance off resonance. How does the circuit work?

Consider a 144-MHz (2 meter) signal coming in on the antenna socket SK2. The tuned circuit L2/C2 is resonant at 144 MHz and, having a low impedance, passes the signal to the 2-meter output SK1. The tuned circuit L3/C3, being resonant at 433 MHz, exhibits a high impedance at 2 meters and so stops the 144-MHz signal from reaching the 70-cm output socket SK3. On 433 MHz the opposite action takes place.

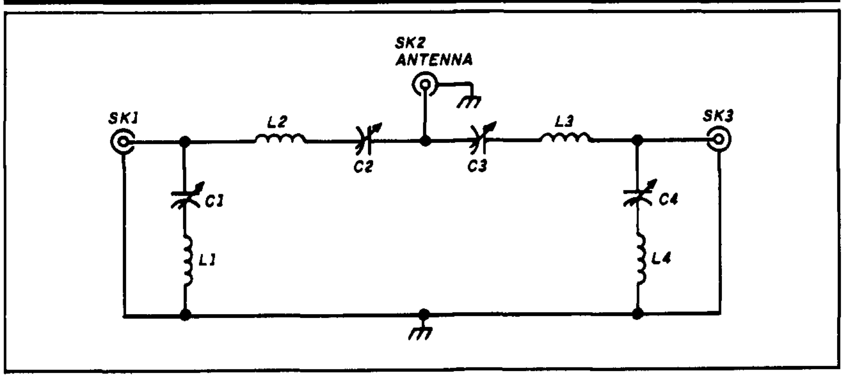
More protection

The action already described will do a fair job, but it can be improved upon.

PARTS LIST

Capacitors		
Trimmers		
C1,3	*5 pF*	
C2,4	*15 pF*	
Inductors		
Air spaced, self-supporting		
L1,3	*3 turns 22 a.w.g., 6 mm diameter, 12.6 mm long*	
L2,4	*5 turns 22 a.w.g., 6 mm diameter, 20 mm long*	
Miscellaneous		
Sockets, BNC, N, etc., as required (3 off); die-cast box; nuts, bolts, washers, and solder tags.		

FIGURE 1



Circuit diagram of the 144 MHz/430 MHz diplexer.

The tuned circuit L1/C1, which is connected from the 2-meter output to earth, is series resonant at 433 MHz and so any signal at that frequency which manages to find its way through L2/C2 is shorted to earth. As it has a high impedance off resonance, L1/C1 has no effect on the 144-MHz signals. The tuned circuit L4/C4 is series resonant at 144 MHz and removes any leakage which reaches the 70-cm output socket at that frequency.

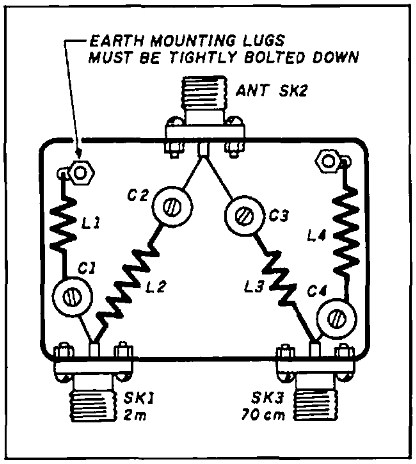
Specification

How well does the circuit do its job? The insertion or through loss was measured at less than 0.1 dB on 144 MHz, and was slightly higher at 0.17 dB on 433 MHz. When you consider that you need a loss of 3 dB to lose one S point of signal strength, these losses can be disregarded. The blocking of 144 MHz at the 70-cm output, and of 433 MHz at the 2-meter output, was greater than 60 dB. This means there's an unwanted output of 1 μW for every watt of power applied, which is more than satisfactory.

Construction

The unit can be built in a small diecast box; a suitable layout is shown in Figure 2. *The trimmer capacitor types required will depend on the transmitter powers to be used. Ceramic piston and compression types are suitable for low powers; for higher powers air-spaced trimmers (e.g., Jackson C804 series) will be necessary. Ed.*

FIGURE 2



A layout suitable for operation at fairly low powers.

Tuning the unit is simple. First connect the rigs to the correct output sockets. **DO NOT TRANSMIT** until all the following steps are completed.

Tune the 144-MHz rig to a strong signal and adjust C2 for the highest S-meter reading. Tune the 433-MHz rig to a strong signal and adjust C3 for the best S-meter reading.

Now connect the 144-MHz rig to the 70-cm output on the diplexer and the 433-MHz rig to the 2-meter output. Tune to a strong 144-MHz signal and adjust C4 for **minimum** S meter reading. Tune to a strong 433-MHz signal and adjust C1 for **minimum** S-meter reading. For safety, run through all the above steps a second time, then reconnect the rigs to the correct outputs and the job is completed.

Glen Ross, G8MWR
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K4EF LONG WIRE ANTENNA DESIGNS

Simple antennas provide exceptional performance

By Everett Brown, K4EF, 6710 Highway 329, Crestwood, Kentucky 40014

My interest in long wires was sharpened in the mid-1970s when I acquired my first solid-state transceiver that required no tuneup. It seemed to me that transmitter technology had left antenna development behind. Wouldn't it be a great improvement to have a single high performance all band antenna fed with a single coaxial cable? Think of the convenience! When operating in contests you could switch bands with no time lost. During a QSO, you could check quickly to see if another band was open. You'd be free to operate on any Amateur HF frequency, without the limitations imposed by antenna bandwidths and high SWR. You could explore every nook and cranny of our extensive frequency allocation and find new friends who rarely leave "home" frequencies. I felt long wires offered the best opportunity to achieve that ideal.

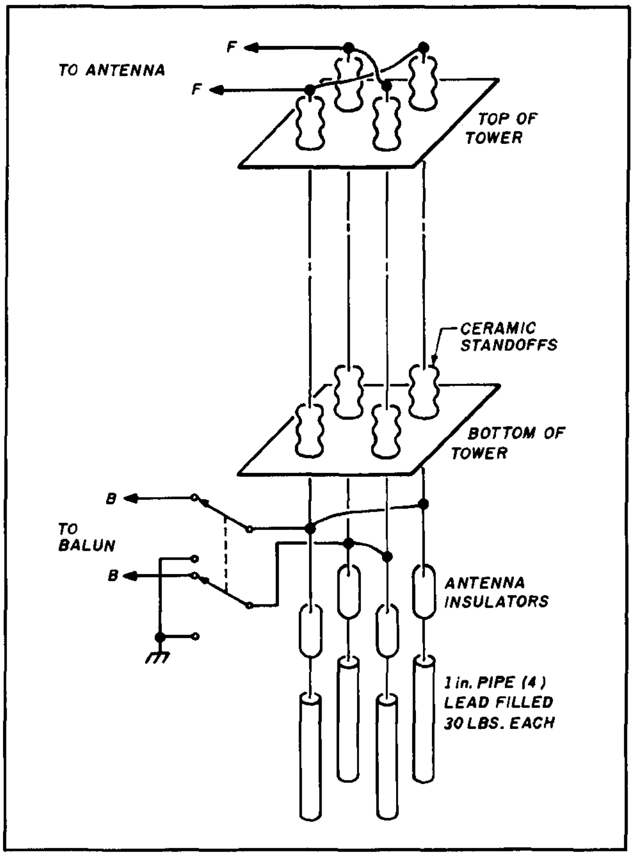
After many months of testing performance on the air and experimenting with numerous configurations, I came to the following conclusions:

- Under skip conditions, V antennas were vastly superior to straight long wires or dipoles. This wasn't due to azimuth gain — they excelled in any direction. Ground wave measurements weren't at all similar to measurements taken during skip contacts.
- A resonant wire, approximately center fed and an odd number of half waves in length, offered a consistent impedance in the vicinity of 200 ohms. If additional wire legs resonant on other frequencies were added, the impedance varied only slightly. If the feedpoint was moved from the center of the element as much as 1/8 wavelength there was surprisingly little shift in impedance.

These findings suggested a whole family of new antenna designs, but I concentrated on my ideal — all bands, one coax. My final design was highly successful and I published it with the associated test and measurement results in the Amateur literature.[1] The final design had one drawback. It occupied about ten acres; not many urban Amateurs could fit it into their backyards. Despite this, I received letters from rural users in many states, and from as far away as VK-land. The Australians were particularly pleased. The antenna performed flawlessly on the commercial frequencies they used in addition to Amateur bands for communications in remote areas.

These antennas are also appealing because they don't require expensive hardware which would oxidize outdoors. I used a single 40-foot wooden mast and aluminum electric fencing wire, which I bought in quarter-mile rolls from commercial suppliers. Trees provided the only other supports.

FIGURE 1



Detail of the 4-wire 200-ohm feedline and grounding relay.

Antenna feed

Feeding a 200-ohm antenna is simple. It requires a 4:1 balun and 50-ohm coaxial cable. Of course, because commercial baluns usually aren't perfect, a word of caution is in order. I suffered a 3:1 SWR on 10 meters for a year before a nearby lightning strike caused the balun to explode like a hand grenade, littering the yard with plastic fragments. Many of the letters from users of identical antennas had reported unity SWR. That lightning strike was a great help. A new balun cured my SWR problem. After the strike, I took more precautions. These involved moving the balun from the top of the mast to the bottom, and installing a 200-ohm open wire line with a relay which grounded the antenna and disconnected the balun automatically when the transceiver was turned off. The 12 volts DC for the relay was supplied by the transceiver power supply. I recommend you try this procedure if you're in an area that experiences frequent electrical storms. Figure 1 shows the details. Four no. 10 copper wires are arranged in a square on 2-inch centers and the diagonally opposite wires are joined together at each end of the line. This line has much lower loss than coaxial cable — a worthwhile bonus. I removed the bolts from the ceramic standoffs and fed the wires through the holes, so the insulators acted as guides. The shelves holding the standoffs had 1-inch holes on the wire centers, providing plenty of clearance. I captured the wires above the top insulators with brass washers that I silver soldered to the wire. If this sounds like a lot of work, there's a shortcut. There was 200-ohm twin lead on the surplus market a few years ago, which would work well in this application. However, finding it is difficult.

The Novice license now allows operation on four HF bands. Old-timers, their backyards already bulging with antennas, may not want to add more for WARC bands. It appears there's an urgent need for multiband antennas to gain access to these new bands, without adding significantly to the hardware already in our yards.

I've come up with some antennas which I think get to the heart of this problem. They're all 200-ohm impedance designs which can be fed with 4:1 baluns and 50-ohm coaxial cable. Most can fit into an urban backyard. You'll notice a few monobanders among the designs. They occupy more space than a conventional dipole; so why use them? The answer is performance. They provide more capture area, and a configuration that has proved superior in extensive on-the-air testing.

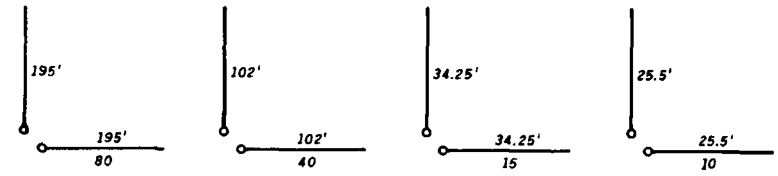
Another feature of these antennas is the 90-degree apex angle, suggesting a V antenna. A V antenna which yields bidirectional gain is fed with the legs *in* phase. These are fed *out* of phase, and this makes them quite different electrically. I couldn't measure any directivity when I used these antennas under skip conditions.

The antenna diagrams in the figures show top views of the antenna wires. Their lengths are identified in feet. The two small circles at the wire ends are the connection points for the 4:1 balun.

Monobanders for the Novice

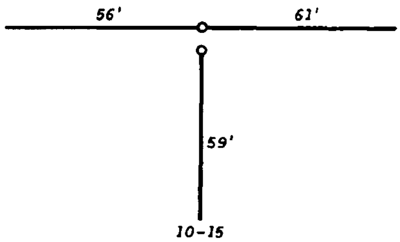
Perhaps you already have several Novice bands covered and wish to add one more. You may want to operate on just one band. In either case, one of the designs in Figure 2 is for you. These designs require three times the wire of a conventional dipole — and for good reason. The configuration and

FIGURE 2



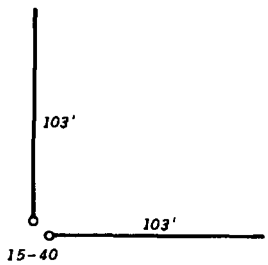
Band	Length of element: Half waves	Feet	Resonant frequency MHz	Bandwidth 2:1 SWR points MHz	Amateur band MHz
80	3	390	3.72	3.66— 3.77	3.70— 3.75
40	3	204	7.11	7.00— 7.22	7.10— 7.15
15	3	68.5	21.18	20.87—21.50	21.10—21.20
10	3	51	28.46	28.03—28.88	28.10—28.50

FIGURE 3



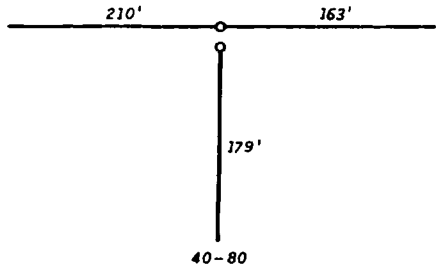
Band	Length of element: Half waves	Feet	Resonant frequency MHz	Bandwidth 2:1 SWR points MHz	Amateur band MHz
15	5	115	21.18	20.86—21.50	21.10—21.20
10	7	120	28.50	28.07—28.93	28.10—28.50

FIGURE 4



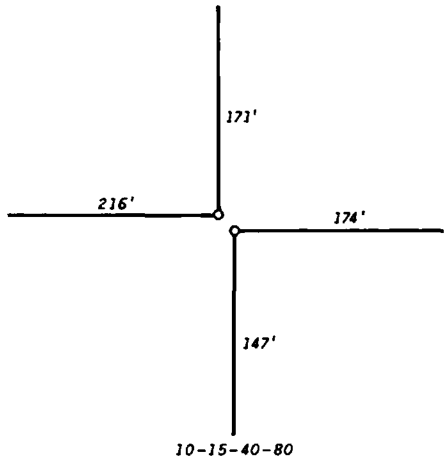
Band	Length of element: Half waves	Feet	Resonant frequency MHz	Bandwidth 2:1 SWR points MHz	Amateur band MHz
40	3	206	7.05	6.94— 7.15	7.10— 7.15
15	9	206	21.38	21.05—21.70	21.10—21.20

FIGURE 5



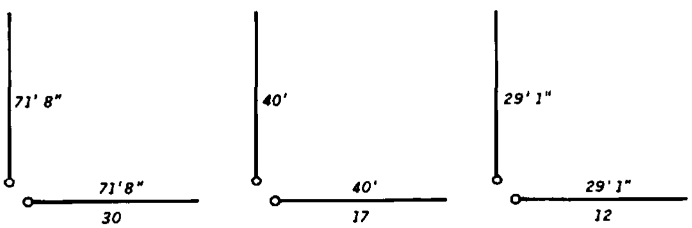
Length of element			Resonant	Bandwidth	Amateur
Band	Half waves	Feet	frequency MHz	2:1 SWR points MHz	band MHz
80	3	389	3.73	3.68—3 79	3.70—3.75
40	5	342	7 12	7.01—7 23	7.10—7.15

FIGURE 6



Length of element			Resonant	Bandwidth	Amateur
Band	Half waves	Feet	frequency MHz	2:1 SWR points MHz	band MHz
80	3	390	3.72	3.67— 3 78	3.70— 3 75
40	5	345	7 06	6 95— 7 16	7 10— 7 15
15	15	345	21 32	21.00—21.64	21 10—21.20
10	21	363	28.40	27.97—28.82	28.10—28.50

FIGURE 7



Length of element			Resonant	Bandwidth	Amateur
Band	Half waves	Feet	frequency MHz	2:1 SWR points MHz	band MHz
30	3	143.3	10 12	9.97— 10.27	10.10—10 15
17	3	80	18 14	17 87—18 41	18.06—18.16
12	3	58.2	24 95	24 58—25.32	24 89—24 99

capture area provide better performance, and they don't have the nulls of a dipole. They are good performers in all directions.

Dual band Novice

This antenna is tailored for the 10 and 15-meter Novice bands (see Figure 3). It's compact and will fit into most backyards. Use one band or the other, without any antenna tuning or switching; the SWR remains low. The cost is also low. All you'll need is under 200 feet of inexpensive wire, coaxial cable, and a balun. Total cost, including insulators and rope, can run as little as $50.

Figure 4 shows an antenna for 15 and 40-meter coverage that uses a little more wire for about the same cost as the preceding design. It's simple to install, and has just two legs. The antenna is resonated in both bands by 206 feet of wire. One antenna does double duty and, like all of these designs, it provides low SWR and excellent performance. If you can't fit the wires onto your property with the 90-degree apex angle, you can make it a straight, center-fed long wire. The SWR will continue to be low; however, the antenna becomes directional and performance suffers on some headings. But this may be your best compromise.

Unfortunately, there isn't a wire length of reasonable dimensions which will resonate on both 80 and 40. The solution is to revert to the three-leg design in Figure 5, which provides a different length for each band. The two resonances fall almost in the center of the Novice segments and this, together with the large area of the array, makes it a very efficient performer. It's ironic that resonances also fall in the 15 and 10-meter bands, but the feedpoint is far removed from the current loops resulting in high SWR on these bands.

All band Novice

The antenna in Figure 6 gives access to all four Novice HF bands. And, when you upgrade to General, it stands ready to serve in other segments. Though I haven't shown it here, the 363-foot element resonates at the high end of 80. This opens 3.9 to 4 MHz up to SSB. In addition; the 345-foot length resonates at the top of the 10-meter band, allowing SSB operation above 29 MHz. This antenna is large, but don't let that deter you. If you have friendly neighbors, you may be able to run unobtrusive wires through the trees over their properties. I did this for a number of years using inexpensive electric fencing wire.

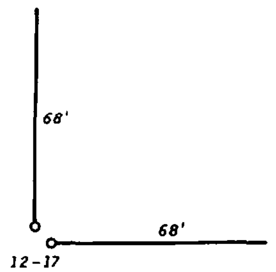
WARC monobanders

The monobanders in Figure 7 are for the ham who wants to add a WARC band. If you cut the wire lengths carefully to the measurements shown, and your antenna is reasonably in the clear, the resonance will fall almost dead center in the band. This will give you a low SWR from band edge to band edge. These element lengths give no resonances on other HF Amateur bands, and shouldn't interfere with existing antennas.

Dual band WARC

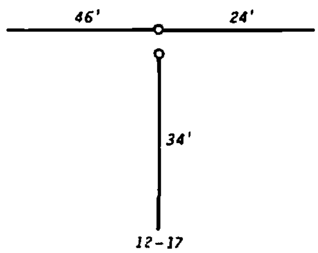
Are you a General who hasn't tried 12 or 17? Here are two antennas which give you both 12 and 17. They are compact and can be erected in the average backyard. I've given two alternatives in Figures 8A and B. Choose the one which best suits your layout. If you have a tower available, use it as the main support with the legs coming down like an inverted V. A flat top, however, is preferable. None of the element lengths

FIGURE 8A



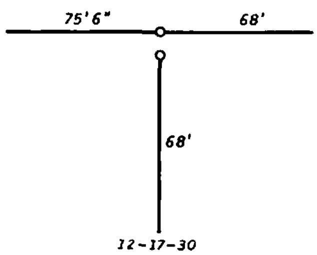
Band	Length of element: Half waves	Feet	Resonant frequency MHz	Bandwidth 2:1 SWR points MHz	Amateur band MHz
17	5	136	17.90	17.63—18.18	18.06—18.16
12	7	136	25.14	24.76—25.52	24.89—24.99

FIGURE 8B



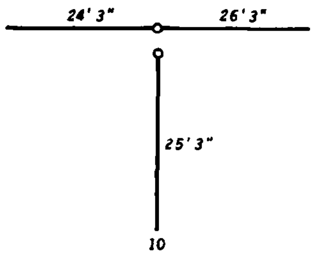
Band	Length of element: Half waves	Feet	Resonant frequency MHz	Bandwidth 2:1 SWR points MHz	Amateur band MHz
17	3	80	18.14	17.87—18.41	18.06—18.16
12	3	58	25.02	24.65—25.40	24.89—24.99

FIGURE 9



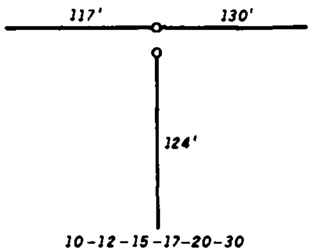
Band	Length of element: Half waves	Feet	Resonant frequency MHz	Bandwidth 2:1 SWR points MHz	Amateur band MHz
30	3	143.5	10.11	9.96—10.27	10.10—10.15
17	5	136	17.90	17.63—18.18	18.06—18.16
12	7	136	25.14	24.76—25.52	24.89—24.99

FIGURE 10



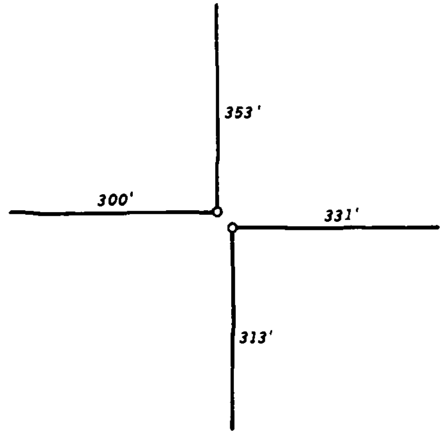
Length of element			Resonant	Bandwidth	Amateur
Band	Half waves	Feet	frequency MHz	2:1 SWR points MHz	band MHz
10	3	51.5	28.18	27.76—29.76	28.00—29.70
		49.5	29.32		

FIGURE 11



Length of element			Resonant	Bandwidth	Amateur
Band	Half waves	Feet	frequency MHz	2:1 SWR points MHz	band MHz
30	5	241	10.10	9.95—10.26	10.10—10.15
20	7	241	14.19	13.98—14.40	14.00—14.35
17	9	241	18.27	18.00—18.54	18.06—18.16
15	11	254	21.21	20.89—21.53	21.00—21.45
12	13	254	25.08	24.71—25.46	24.89—24.99
10	15	254	28.95	28.52—29.30	28.00—29.70

FIGURE 12



Length of element			Resonant	Bandwidth	Amateur
Band	Half waves	Feet	frequency MHz	2:1 SWR points MHz	band MHz
80	5	613	3.97	3.50—4.03	3.50—4.00
	5	631	3.86		
	5	666	3.66		
	5	684	3.56		
40	9	613	7.18	6.80—7.30	7.00—7.30
	9	631	6.98		
30	13	631	10.00	9.95—10.25	10.10—10.15
20	19	666	14.00	13.79—14.35	14.00—14.35
17	23	613	18.42	17.62—18.70	18.06—18.16
	23	631	17.89		
12	31	613	24.84	24.46—25.21	24.89—24.99
10	35	613	28.05	27.63—29.24	28.00—29.70
	37	631	28.81		
	39	666	28.77		
	39	684	28.02		

on the three-leg design resonate on or near other Amateur bands, so it shouldn't pose a problem for your Yagis or other antennas. The three-leg design also provides a somewhat lower SWR. On the other hand, the two-leg design *will* resonate on 40, 20, and 10 meters, and should be kept clear of other antennas on those bands.

Triband WARC

Here's your chance to put up one antenna with capabilities on *all* WARC bands! (See **Figure** 9.) While these designs will function satisfactorily when installed as inverted Vs, it's preferable to make them flat tops. Unlike a dipole, which has a single current loop at the center, these antennas have at least three current loops (including one in the center). The current loops provide maximum radiation.

Broadband 10-meter monobander for general coverage

Because this band is so much wider, it poses problems of band coverage with narrowband antennas. The design shown in **Figure** 10 will cover the entire band. Don't use a coaxial balun; it will limit your bandwidth. If you wind your own, use the Amidon iron powder kit with eight bifilar turns instead of the usual ten. On this HF band, worry about coaxial cable losses. RG-58, with a run of 100 feet and transceiver output of 100 watts, will deliver only 56 watts to the antenna. By comparison, Belden 9913 or equivalent will deliver 85 watts to the antenna in similar circumstances on 10 meters.

Six band general coverage

The simple antenna in **Figure** 11 will deliver six of the nine HF bands! It provides the traditional DX bands, plus all WARC frequencies. The resonances fall within all the bands but 17 and 12, where they are slightly on the high side. However, the antenna bandwidth amply covers these two WARC bands with an SWR of less than 2:1. A commercial balun will handle this design; but if you use a kit and wind your own, I suggest once again that you use eight turns instead of the usual ten. The fewer turns will slightly lower SWR on 10 and 12 meters.

Eight band general coverage

This is the "Monster." It covers about ten acres (see **Figure** 12). Since the publication of the details of this design[1] it has been used in many states and DX locations. Nearly all users reported SWR readings on each band similar to those I had experienced.

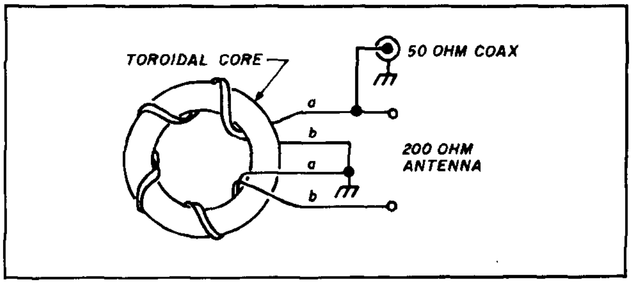
All of the preceding antennas require a 4:1 balun to give a good match with RG-58 or RG-8 type 50-ohm coaxial cable. I have provided several options.

Toroid balun

There are a number of commercial baluns available from Amateur equipment distributors. Be sure you get a 4:1, not a 1:1 (see **Figure** 13). If you'd like to wind your own, you can order a kit from Amidon Associates or Radiokit.* They come with instructions suggesting they be packaged in PVC pipe. I recommend you wrap the core with Scotch® no. 27 glass electrical cloth tape. You can get epoxy potting material from your local electrical supply house and completely encapsulate the unit. The final professional touch for the ultimate in reliability is to do the potting in a high school or college science lab, and immediately place it in a vacuum jar. This removes all bubbles or moisture.

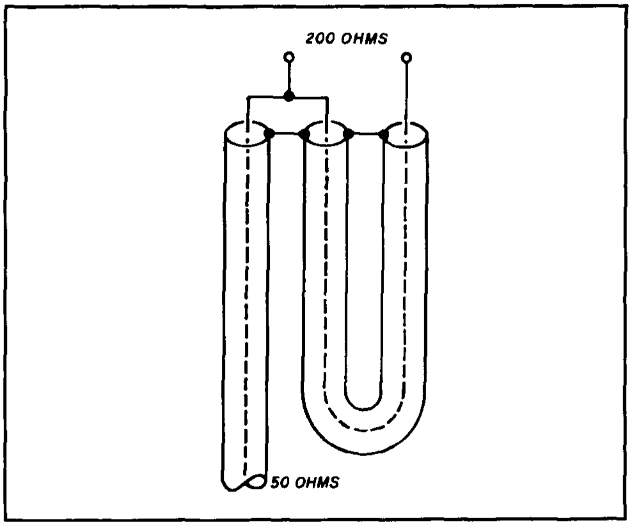
*Amidon Associates, 12033 Otsego Street, North Hollywood, California 91607.
Radiokit, Box 973, Pelham, New Hampshire 03076. (603) 633-2235

FIGURE 13



Detail for winding a 4:1 balun.

FIGURE 14



Detail for making coaxial balun.

Coaxial balun

You can make your balun of coaxial cable for **some** of the monoband antenna designs I've described. Details are shown in **Figure** 14. The U section may be coiled and secured with tape; its length is as follows:

Coaxial cable length U section

Band	Solid	Foam
80 Novice	87'2"	104'4"
40	45'7"	54'7"
30	32'1"	38'5"
17	17'10"	21'6"
15	15'4"	18'5"
12	13'	15'7"
10 Novice	11'5"	13'8"

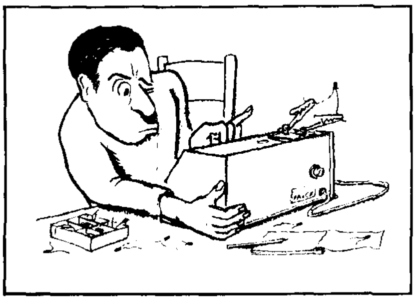
Conclusion

I hope you'll give one of these long wire antenna designs a try. Pick a band (or bands) that your existing antenna system doesn't cover, and put one to the test. I'll look for you on the air!

REFERENCES
1. E.S. Brown, K4EF, "Antenna Design Using the Long Wire Principle," *Ham Radio*, May 1977, page 10

Practically Speaking

Joseph J. Carr, K4IPV



VERTICALLY POLARIZED HF ANTENNAS: PART 2

Last month I introduced a series on vertical antennas. I discussed the basic theory and configuration of the "standard" quarter-wavelength vertical antenna. This month I'll take a look at some practical issues involving the much-needed ground system for the vertical, and vertical antenna construction details.

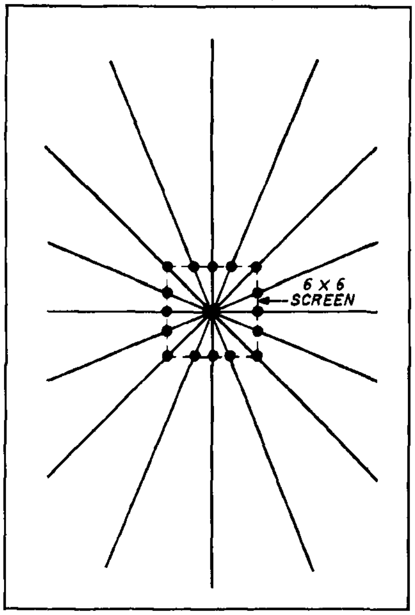
Vertical antenna ground systems

The vertical antenna works well only when placed over a good ground system. The usual way to provide a good ground for a vertical is to use a system of radials like that shown in **Figure 1**. A view from above shows 16 quarter-wavelength radials arranged to cover a full circle around the antenna. Each radial is a quarter wavelength, so each will have a length (in feet) of $246/F_{MHz}$. All the radials are connected together at the base of the antenna, and the ground side of the transmission line is connected to this system. The radials may be placed on the surface or underground. A friend of mine placed an extensive radial system on the bare dirt when his house was being built. When the sod was laid down, he had a very high quality underground radial system.

If you decide to use an above-ground radial system, be sure to make provisions to prevent people from tripping over it. You may be liable if people trip over your radials and injure themselves — even if the person is an intruder or trespasser!

Some experts prefer to place a copper wire screen at the center of the radial system. The minimum screen size is about 2 meters (6 feet) square. Use solder to connect it to the radials at the points shown in **Figure 1**. Other experts drive ground stakes into the ground at these points. Still another method is shown in **Figure 2**. Here you see a "spider web" of conductors shorting the radials at points a meter or two from the antenna. Again, some authorities recommend that ground rods be driven into the earth at the points indicated.

FIGURE 1

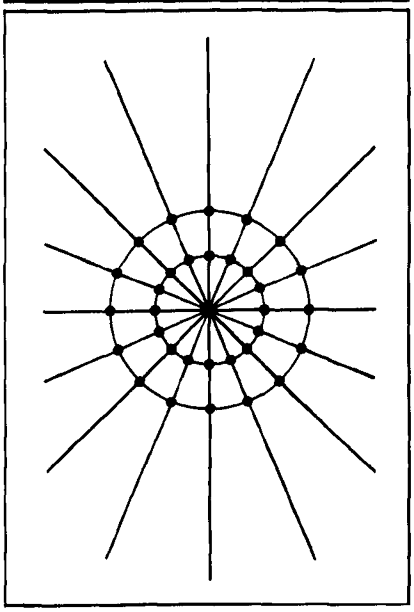


Basic ground radial system.

The exact number of radials you use depends in part on practical matters — like how much money you have to spend, or how many you can physically install. Use at least two radials per band; four per band is preferred for simple, low cost systems. However, be aware that even four radials is considered a compromise. The general rule is: the more radials, the better. But there's also a law of diminishing returns as the number of radials increases. **Figure 3** shows the approximate field intensity (mV/meter) as a function of the number of radials. Notice that the field intensity doesn't increase as rapidly per extra radial when the total number of radials is above 20 or so. The Federal Communications Commission requires AM band (550 to 1620 KHz) stations to use 120 radials, but that number isn't necessary for Amateur stations. A practical upper limit of 16 radials is usually accepted for Amateur radio work, and your antenna can work well with fewer.

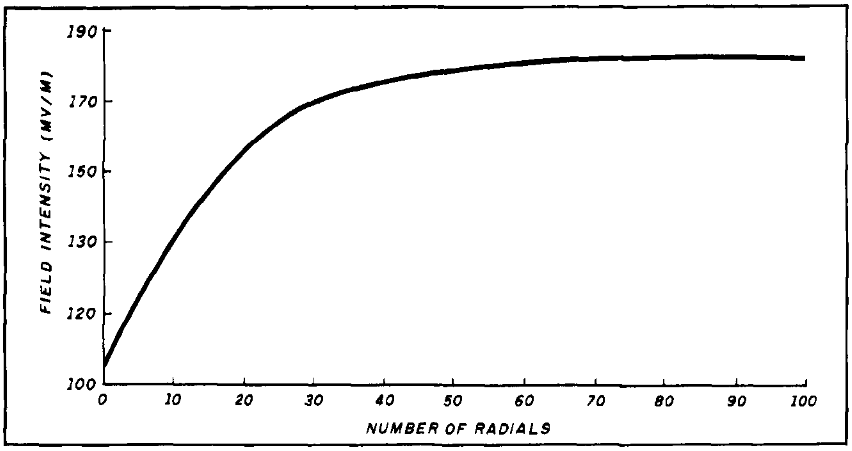
For vertical antennas mounted above ground, there's an optimum height for the base of the antenna. This height is a quarter wavelength above the actual ground plane. Unfortunately, that distance may or may not be the actual physical height above the surface. Depending upon ground conductivity and ground water content, the height may be exactly a quarter wavelength above the surface or

FIGURE 2



Spiderweb ground radial system.

FIGURE 3



Effect of the number of radials on the effective radiation of the antenna.

slightly lower. Find the optimum height by experimenting; remember that it will vary over the course of the year if climatic changes are the norm in your location.

Vertical antenna variants

So far, the vertical antennas I've considered have been standard quarter-wavelength models. Let's take a look at several variations. **Figure 4** shows the vertical half-wavelength dipole. The vertical dipole is constructed in exactly the same manner as the horizontal dipole, but is mounted in the vertical plane. In general, the section of the radiator closest to the ground should be connected to the shield end of the coaxial cable transmission line.

Like the horizontal dipole, the approximate length of the vertical dipole is calculated from:

$$L_{ft} = \frac{468}{F_{MHz}} \quad \textbf{(1)}$$

Where:

L_{ft} is the length in feet, and

F_{MHz} is the operating frequency in megahertz.

Of course, each leg of the vertical dipole is one-half the calculated length.

The vertical dipole antenna is used in many locations where it's impossible to mount a horizontal dipole properly, or where a roof or mast-mounted antenna is impossible to install because of logistics or a hostile landlord and/or homeowners' association. Some row and townhouse dwellers, for example, have been successful with the vertical dipole. In the 1950s and 1960s, the vertical dipole was popular among European Amateurs because of space restrictions in many locations.

Vertical dipole construction is relatively straightforward. First, find or build a vertical support structure. In the system shown in **Figure 4**, the support is a wooden or heavy wall PVC mast. Thin wall PVC pipe whips around too much in the wind and requires more guy line support than is reasonable; so avoid it for this application. Ropes and insulators at either end support the wire elements from the ends and keep the antenna taut. If neighbors are a problem, try to find some white thick wall PVC pipe that you can use to build a fine flagpole (be patriotic), and simply hide a vertical dipole inside it. If your home doesn't have metal siding and is tall enough, a support from the roof structure (or soffits) will make a proper support.

One problem we liability-conscious people need to consider when using a vertical dipole is the high impedance voltage at the ends of a half-wavelength dipole. Anyone touching the antenna is likely to receive a nasty RF burn or shock.

Coaxial vertical construction is similar to that of the vertical dipole in that it uses a pair of vertical radiator elements. It can even be argued that it's a form of vertical dipole. However, with the coaxial vertical antenna, the radiator that's closest to the ground is coaxial with the transmission line and the main radiator element (see the example in **Figure 5A**). An insulator at the feedpoint separates the two halves of the radiator. In most cases, the top radiator is smaller in diameter than the coaxial sleeve (also called the "shield pipe" in some publications). For the most part, the reasons for this arrangement are mechanical rather than electrical. The coaxial cable transmission line passes through the sleeve and is *itself coaxial to the sleeve.*

The overall length of the coaxial vertical antenna is one-half wavelength, consisting of two quarter-wavelength sections. Both the radiator and the sleeve are a quarter wavelength long. The starting length of each is found (approximately) from:

$$L_{ft} = \frac{246}{F_{MHz}} \quad \textbf{(2)}$$

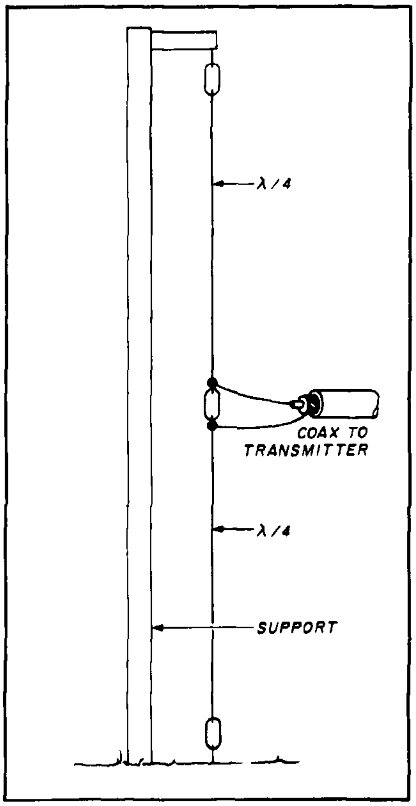
or,

$$L_{meters} = \frac{72}{F_{MHz}} \quad \textbf{(3)}$$

These equations are similar to the one used to calculate half-wavelength antennas, but they are reduced by a factor of 2.

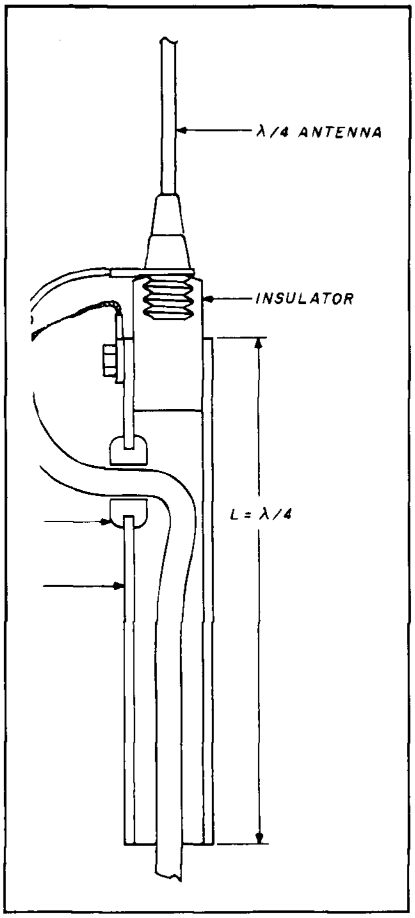
The coaxial vertical antenna was once popular with CB operators and was called the "colinear antenna." You can sometimes find hardware from these antennas at hamfests or surplus

FIGURE 4



Simple half-wave vertical dipole.

FIGURE 5A



Commercially used system for feeding a coaxial half-wave antenna.

markets and modify the pieces for Amateur Radio use. If you're building a 10-meter band antenna, it's a simple matter to cut the 11-meter CB antenna for operation on a slightly higher frequency. But it's a little more difficult for the lower frequency bands, and it's likely that only the insulator and mounting assembly are salvageable. Keep in mind, however, that adjacent sizes of aluminum tubing are designed so that the inner diameter (ID) of the larger piece is a slip fit for the outer diameter (OD) of the smaller piece. This lets you connect adjacent sizes of aluminum tubing together without special couplers. I find that salvaged insulator assemblies with just 6 to 10 inches of the former radiator and sleeve can be cut off, and new radiators from "adjacent size" tubing can be installed.

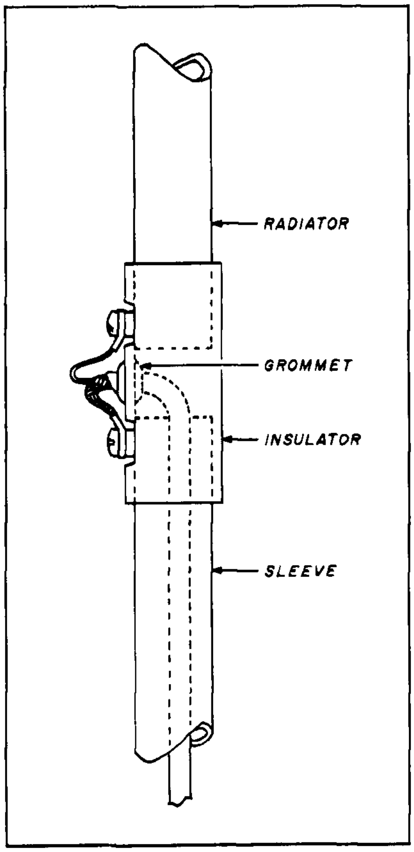
The configuration in **Figure 5A** is the construction technique used by commercial antenna manufacturers for VHF and CB colinear vertical dipoles. This method is a little difficult for those who don't have access to a machine shop for making the center insulator. You'll need to find another construction method to make this antenna practical.

Figure 5B shows a construction method that has been used by Amateurs with good results. The radiator and shield pipe (sleeve) are joined together in an insulating piece of thick wall PVC plumbing pipe, Lucite™, or Plexiglas™ tubing; 6 to 10 inches of tubing are needed.

Leave a gap of about 2 inches between the bottom end of the radiator pipe and the top end of the shield pipe to keep them electrically insulated from each other, and to allow the coaxial cable to be passed through to the outside world. Drill a hole in the insulator pipe for this purpose.

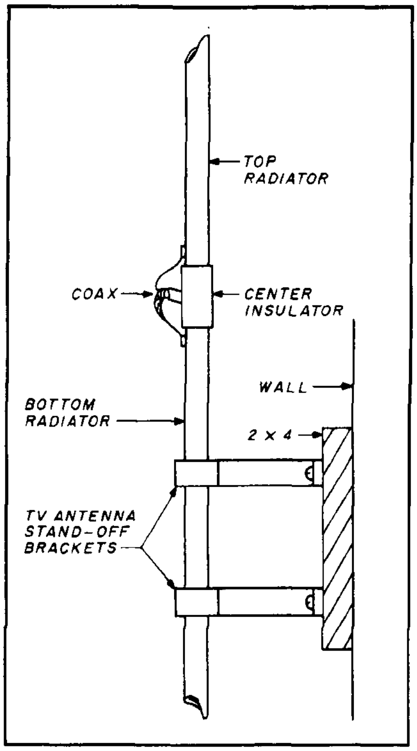
Fasten the aluminum tubing pieces for the radiator and the sleeve to the insulator using at least two heavy machine screws for each. You can use one of the machine screws on each piece as the electrical connection

FIGURE 5B



Homebrew method for feeding a coaxial half-wave vertical.

FIGURE 5C

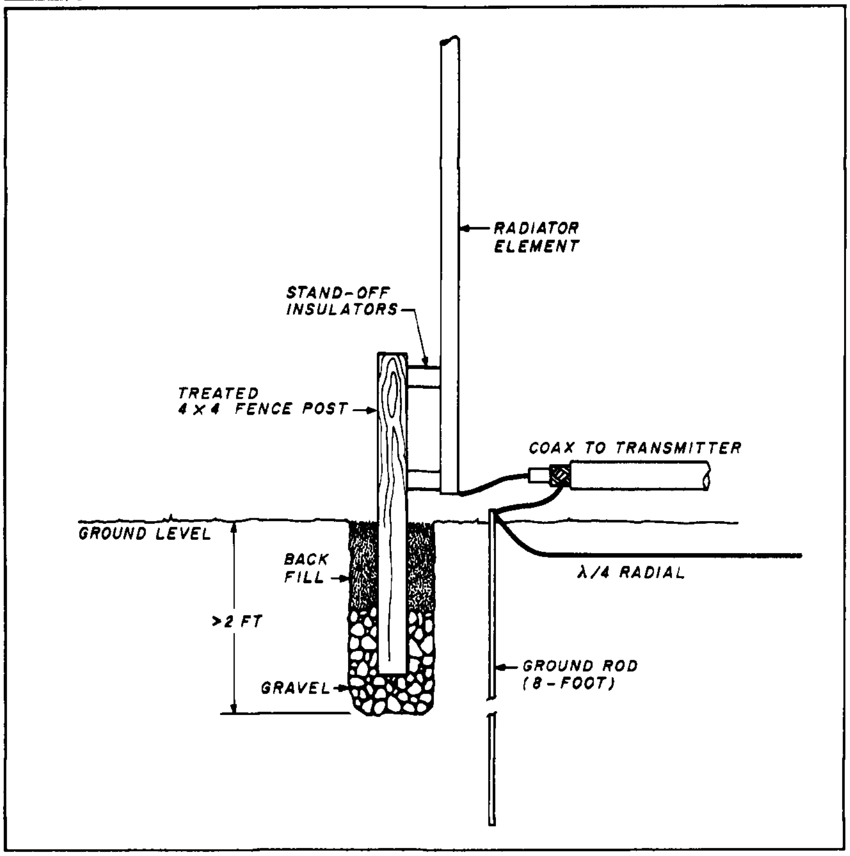


Antenna mounting scheme.

between the coaxial cable and the pipes, as long as you cut a larger hole in the insulator at that point to admit the washer that provides the electrical pathway between the screw head and the aluminum pipe. If you omit the washer, and depend on the contact between the machine screw and the pipe, your connection will probably be intermittent and cause you quite a bit of aggravation.

Mounting the homebrew coaxial vertical antenna can be a "pain in the neck." Normally this antenna is mounted high in the air, so some form of support is needed. Fortunately, you can use small area metal supports connected to the sleeve. **Figure 5C** shows one popular mounting method that uses a pair of television antenna standoff mounting brackets to support the sleeve. You can buy these brackets in sizes from 6 to 24 inches. Note that a 2 × 4 piece of lumber is used between the building wall and the brackets. This wood serves as an insulator, so it should be varnished or painted. Attach it to the wall with lag bolts, wing bolts, or some other secure anchoring method. Keep in mind that the forces on the brackets increase tremendously during windstorms.

FIGURE 6



Basic ground installation of a quarter-wave vertical.

The two vertical antennas shown here can present a shock hazard to anyone who touches them. Both of those antennas are half-wavelength radiators and of the dipole form of construction. The center point is used for feeding the antenna, so it forms the low impedance point in the antenna. As a result, the ends of the antenna, one of which is close to the ground, are the high impedance points. This means the voltages at those points can be high, and also within reach of prying hands playing in the yard. It's wise to either mount the antennas so far above ground that they can't be reached, or build a small nonconductive fence around the ends of the antenna.

Vertical antenna construction

Vertical antenna installations are generally ground level or nonground mounted. In this section I'll take a brief look at both forms of mounting, concentrating on the installation of homebrew verticals rather than commercial ones. I assume that the vendors of these antennas will provide their own instructions.

The ground-level mounted vertical is shown in **Figure 6**. The typical vertical antenna is 8 to 40 feet high. Thus, although the actual weight of the antenna is small, *the forces applied to the mounting structure can be quite high, especially during windstorms.* Don't be fooled by the apparent light weight of the antenna in this respect.

The mounting structure for the vertical antenna can be a metal or wooden fence post buried in the ground. Make sure at least 2 feet of the fence post are above ground. In **Figure 6**, a 4 × 4 wooden fence post is used as the mounting, but the principles are similar for all forms of post. Try to make sure you have a fence post hole at least 2 feet deep. In some cases, it may be possible to use 1 foot of gravel fill topped with back-filled dirt. In other cases, especially where a steel fence post is used, place a concrete plug at the bottom of the hole over a 4-inch layer of gravel.

Install the antenna radiator element to the fence post with standoff insulators. You may have to omit these insulators, as they are difficult to find. Given that varnished or painted wood isn't a very good conductor, it's not unreasonable to bolt the radiator directly to the 4 × 4 fence post. Use 5/16-inch (or larger) bolts; make sure they're long enough to fit through both the antenna element and the 4 × 4 post. Bolts 5/16 inch in diameter and 6 or 8 inches long will probably work best. Use at least two bolts, one at the bottom of the antenna radiator element and one near the top of the fence post. A third bolt, halfway between the other two, wouldn't be out of order.

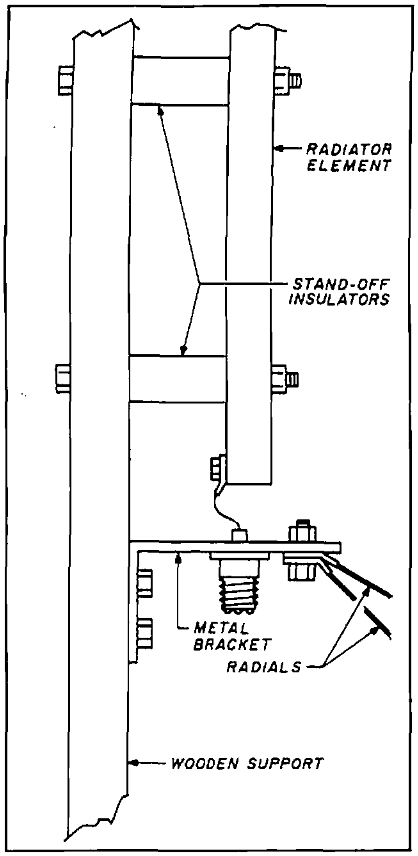
Generally, no matching is necessary if the antenna is a quarter wavelength. Although the feedpoint impedance isn't exactly 52 ohms, it's close enough (37 ohms) to form a reasonable match for 52-ohm coaxial cable (with VSWR ≃ 1.4:1). The center conductor of the coaxial cable is connected to the radiator element, while the shield is connected to the ground system. Two ground methods are used in the example shown in **Figure 6**. The first is an 8-foot ground rod driven into the earth at the base of the antenna; the second is a system of quarter-wavelength radials. Remember that the ground system is absolutely essential.

Figure 7 shows a method for installing a vertical antenna above ground. A wooden support (2 × 4 or 4 × 4) is put up in a manner similar to the one in **Figure 6**, but a deeper hole is used to counter the longer length. The support can also be affixed to the side of a building wall, shed, or other preexisting structure. Once you've decided on your support, attach the radiator element using the method described for the previous antenna.

Electrical connections to the antenna are also shown in **Figure 7**. Because the antenna is above ground level, an electrical counterpoise ground consisting of a system of radials is absolutely essential; provide at least two radials per band. Use a small L bracket to support the radials and provide an SO-239 coaxial connector for the coax. This connector is a chassis-mounted type with its center conductor connected to the radiator element. Fasten the connector shield to the bracket; this connects it to the radial system.

In some installations the antenna support structure will require guy wires

FIGURE 7



Scheme for mounting an elevated vertical with an elevated radial system.

to keep the structure stable. Don't use the radials as guy wires. The type of wire that usually works well for radials is too soft and too easily stretched for guy wire service. Use regular steel guy line, available where TV antenna supplies are sold, for this antenna. Make the lengths nonresonant and break the guy lines up with egg insulators, if necessary, to achieve nonresonance.

Next month...

I'll look at two topics in the final installment of this three-part series. One is the 5/8-wavelength vertical antenna. These verticals have a generally lower angle of radiation than quarter-wavelength antennas, and may offer many Amateurs a superior "DX solution" over the quarter-wavelength model. The second issue that I'll address is safety.

I can be reached at POB 1099, Falls Church, Virginia 22041; I'd like to have your comments and suggestions for this column.

✓ 146

CARD FILE STATION FOR 40 METERS

By Ed Marriner, W6XM, 528 Colima St., La Jolla California 92037

I'd like to tell you about a 40-meter CW transceiver I use for portable QRP. It consists of a direct conversion receiver and a 1-watt transmitter (see **Figure 1**).

A direct conversion receiver is very good for portable use. It has disadvantages as a home station if there are other stations within a mile of you. A strong signal nearby will block and modulate across the band.

The direct conversion receiver VFO is tuned just off frequency from the incoming signal. This difference in frequency produces a clean, strong, and solid audio tone signal.

You'll find when tuning that adjacent signals may superimpose themselves on the received signal if the band is crowded. You could use an audio filter; however, this would add to the complexity of the receiver. Tuning to one side or the other of the received signal sometimes deletes the unwanted signal. Your only other alternative for solving the interference problem is to find a crystal filter for a regular superhetrodyne receiver Unfortunately, this is almost impossible because parts are becoming hard to get.

Even though the direct conversion receiver has some drawbacks, it gives me a lot of enjoyment during the day when there are few signals on the band. Best of all, these receivers are simple.

Power supply

I'd like to suggest that you start by using a 12-volt battery for the power supply. Doing so solves a lot of problems. You can experiment with a 12-volt regulated supply later. I use a regulated supply built in a Ten-Tec box and keep it at least a foot away from the receiver. It's been recommended that toroid chokes be used in both positive and negative leads when using AC supplies with a direct conversion receiver. I didn't find it necessary. Don't try to build the power supply and transceiver on the same chassis. If you do you're bound to have AC-modulated hum. Transistors love to pick up this hum from the chassis ground.

I built my transceiver in a 3 × 5-inch wooden card file box. You might want to use a larger chassis.

Audio amplifier

I used a Radio Shack telephone amplifier (catalog no. 43-231) which is often on sale for $7.00. I found it was a great choice. The amplifier contains a 2N2222 audio preamplifier driving an LM386. I was able to use the whole board by removing it from the case. (Just two screws hold it in place.) I also used the loudspeaker; it can be pried from the case. I could have used the amplifier volume control, but I used a standard 10-k potentiometer for panel mounting instead.

PC boards

I made my own circuit board using drafting dots and tape. You can hacksaw the board using two pieces of angle iron for support. Make sure you file the edges until they're smooth. Polish the copper with steel wool before putting on the tape.

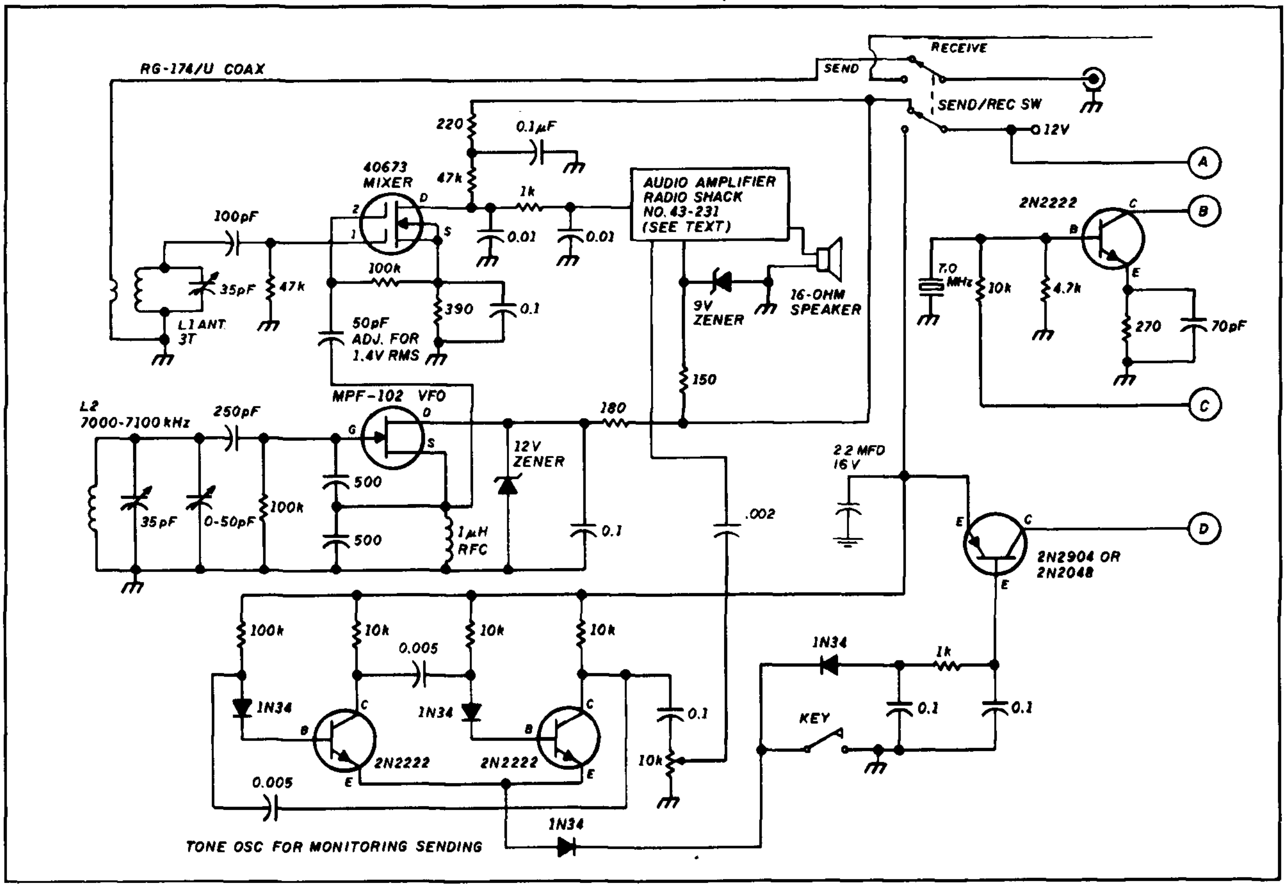
I used to put the components on the fiber side of the board. Now I put them on the copper side; this makes it easier to remove or change them. There are times when leads coming through holes are covered with solder and still aren't making contact. It's easier to solder the components if you tin the copper side.

Once the board circuitry tape is pasted on, I put the board in a plastic tray and pour ferric chloride over it. Place a 75-watt lamp over the tray to heat the fluid. The Radio Shack board etches in about 20 minutes. Many military-type boards have thicker copper and are very difficult to etch. The process may take up to an hour. I found both the board and etchant at Radio Shack.

Coil construction

I find winding and tuning the toroid coils the most difficult part of construction. Everyone has various sizes in their junkboxes and this makes a grid dip oscillator (GDO) a must. The T-68 or T-50 coils are the most popular. For 40 meters use the red-painted ones. You can start by winding 35 turns of no. 28 wire on the coil. Fasten the coil to a 50-pF variable capacitor, then put one loop of hookup wire

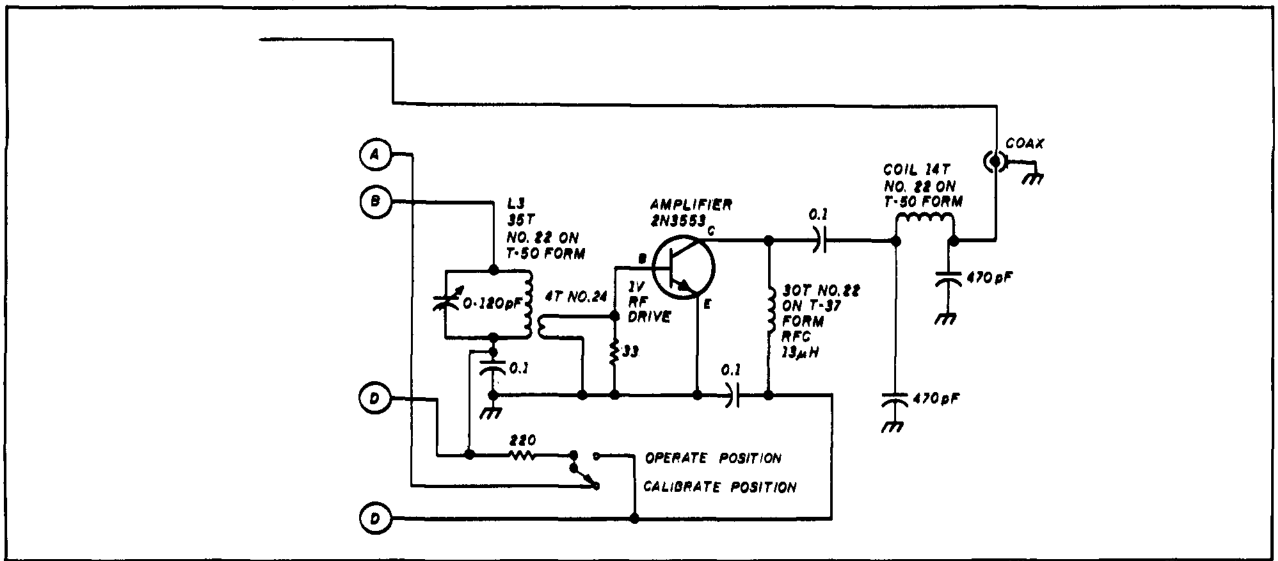
FIGURE 1



Schematic of the 40-meter direct-conversion receiver and 1-watt transmitter.

(Continued on page 61.)

FIGURE 1



through the hole. Put a loop of wire around the dipper coil and clip to the loop around the toroid coil, which has been set to 50 to 75 pF. Adjust the turns for resonance for 40 meters.

You can detect the resonant frequency of the transmitter variable frequency oscillator (VFO) by using the GDO as a field-strength meter. Because of the large capacitance in the Colpitts VFO, the tuning coil will have less turns than the mixer coil. Use the capacitance shown for the VFO gate to ground (see **Figure 1**) and to the coil. It will affect the frequency and output. You'll need 1.4 volts rms on pin 2 of the mixer to get a good signal from the VFO.

The 1000-ohm resistor and 0.01-μF capacitors act as an RF filter from the mixer ouput. You can use a 2.5-mH RF choke, but I found it wasn't necessary.

Transmitter

The transmitter is straightforward. The oscillator coil is peaked to obtain 1 volt of RF drive to the 2N3553. The output of the final matches 50-ohm coax line.

Parts are hard to find these days. I've listed some places to try here. Perhaps an ad in *Ham Radio* might net you some hard-to-find parts.

Toroids
Palomar Engineers, Box 455, Escondido, California 92025.
Amidon Electronic Supply, 12033 Otsego Street, North Hollywood, California 91607.

Transistors
All Electronics Corp., P.O. Box 567, Van Nuys, California 91408.
Circuit Specialists, P.O. Box 3047, Scottsdale, Arizona 85271.
RF Parts, 1320 Grand Avenue, San Marcos, California 92060.

Variable capacitors
Fair Radio Sales Company, 1016 East Eureka Street, Lima, Ohio 45802.
Search the magazine ads and write for surplus. You might also try radio swap meets.

INTRODUCTION TO WAVEFORM GENERATORS PART 1

By Joseph J. Carr, K4IPV, P.O. Box 1099, Falls Church, Virginia 22041-1099

Waveform generator circuits are used to produce a large variety of waveforms needed in circuits and projects of interest to Amateur operators. The astable (also called free running) multivibrator (AMV) may produce square waves, triangle waves, or other nonsinusoidal waveforms. The AMV is a circuit that produces a periodic waveform (i.e., one that repeats itself).

The monostable multivibrator (MMV), or one-shot, circuit is a class of waveform generator that is not free running. This circuit produces only a single pulse when triggered, so it isn't periodic. (Note: In the strictest sense, astable multivibrator circuits produce only square waves. Current common usage, however, broadens the scope of the term considerably.)

The subclass of AMV and MMV circuits I'll discuss here is based on IC devices like voltage comparators, operational amplifiers, integrators, and so forth. Because these circuits are based on the charge and discharge properties of resistor-capacitor networks, it's prudent to review the operation of simple RC networks. Since they also depend on the properties of the op amp voltage comparator, I'll review comparator theory.

Review of RC networks

Take a look at **Figure 1A**. Assuming that the initial condition is as shown, switch S1 is in position A and is open circuited. Initially, there's no charge stored in capacitor C (i.e., Vc = 0). However, if switch S1 is moved to position B, voltage V is applied to the RC network. The capacitor begins to charge with current from the battery, and Vc begins to rise towards V (see curve Vcb in **Figure 1B**). The instantaneous capacitor voltage is found from:

$$V_C = V[1 - e^{(-T/RC)}] \quad \textbf{(1)}$$

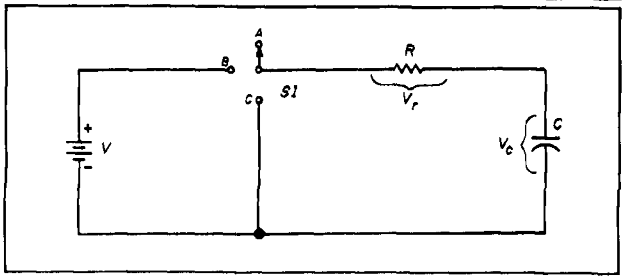
Where:

Vc is the capacitor voltage

V is the applied voltage from the source

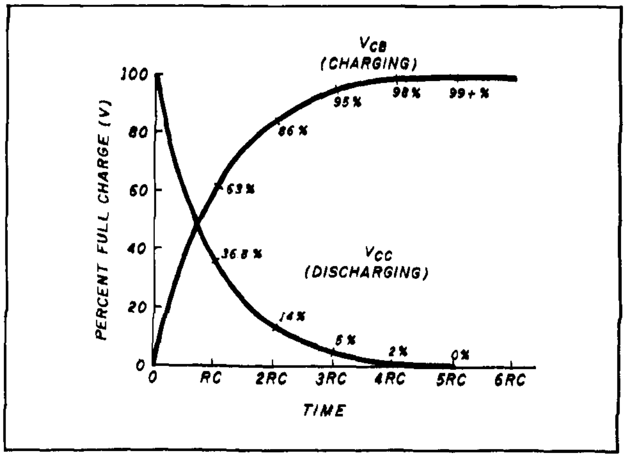
T is the elapsed time (in seconds) after charging begins

FIGURE 1A



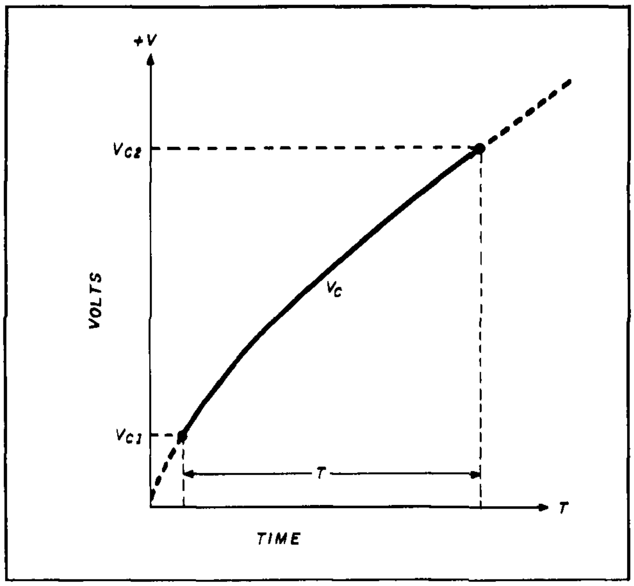
Basic RC network, no voltage applied.

FIGURE 1B



Graph illustrating charge and discharge time constants.

FIGURE 1C



Graph of a common charge cycle encountered in waveform generators.

R is the resistance in ohms
C is the capacitance in farads
The product RC is called the RC time constant of the network. If R is in ohms and C is in farads, then the product RC is specified in seconds. The capacitor voltage rises to approximately 63.2 percent of the final value after 1RC, 86 percent after 2RC, and >99 percent after 5RC. By definition, a capacitor in an RC network is considered "fully charged" after five time constants.

If switch S1 in **Figure 1A** is next set to position C, the capacitor begins to discharge through the resistor. In the discharge condition:

$$V_c = V[e^{(-T/RC)}] \tag{2}$$

Voltage Vc drops to 36.8 percent of the full charge level after one time constant (1RC), and to very nearly zero after 5RC.

Now look at **Figure 1C**. This graph represents a situation commonly encountered in waveform generator circuits. In this graph, the capacitor is required to charge from some initial condition (Vc1), which may or may not be zero volts, to a final condition (Vc2), which may or may not be the fully charged 5RC point. This all occurs in a specified time interval, T. The question is: "What RC time constant will force Vc1 to rise to Vc2 in time T? Assuming that $V_{c1} < V_{c2} < V$:

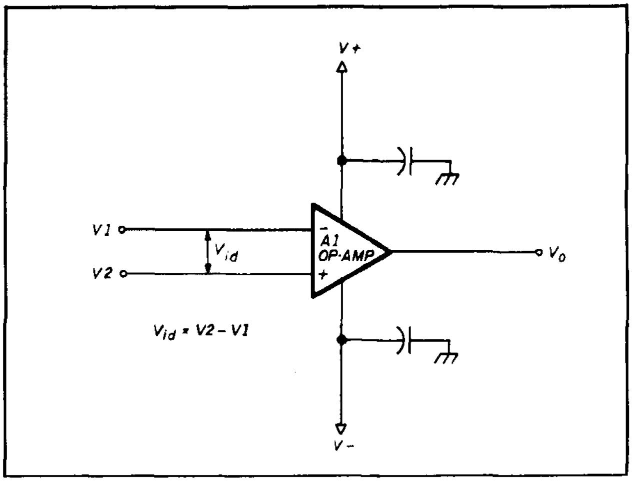
$$V - V_{c2} = (V - V_{c1})[e^{(-T/RC)}] \tag{3}$$

or, doing a little algebra and rearranging terms:

$$RC = \frac{-T}{Ln\left[\dfrac{V - VC2}{V - VC1}\right]} \tag{4}$$

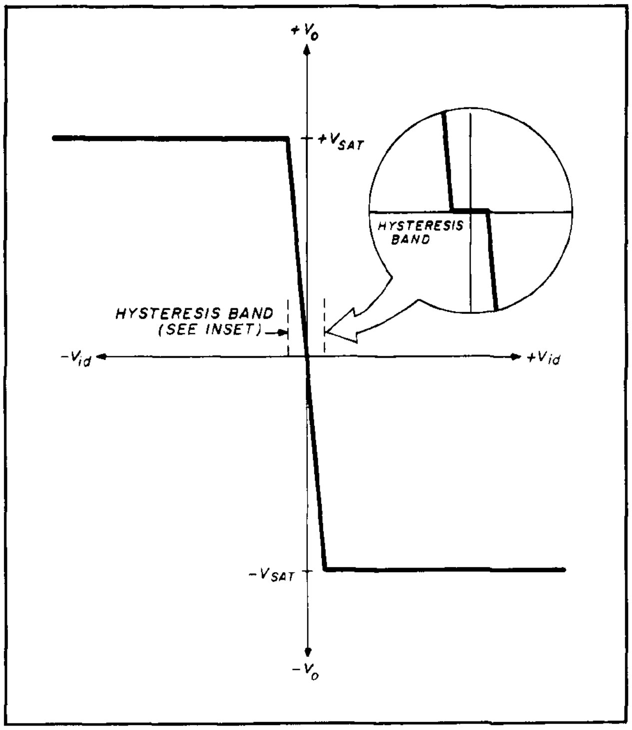
You can use **Equation 4** to derive the timing or frequency setting equations of many different RC-based waveform generator circuits. The key voltage levels will most often be comparator trip points, or critical values set by the design of the circuit.

FIGURE 2A



Basic voltage comparator using an op amp.

FIGURE 2B

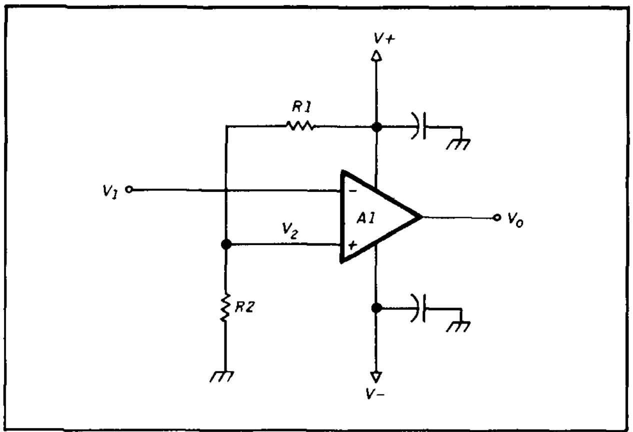


Graph depicting the transfer function of the comparator.

Voltage comparators

A voltage comparator is basically an operational amplifier without a negative feedback network (see **Figure 2A**). The open loop gain of the operational amplifier is very large, on the order of 200,000 to 300,000 for most common, low cost integrated circuit (IC) devices. Without a negative feedback, the operational amplifier functions as a very high gain DC amplifier with an output that saturates when a very tiny input potential is present.

FIGURE 3A



Simple method for biasing either input to the comparator to a specific voltage.

The voltage comparator is used to compare two input voltages and issue an output signal that indicates their relationship (V1 = V2, V1 > V2, or V1 < V2). In **Figure 2A** potential V1 is applied to the inverting input, and V2 is applied to the noninverting input. If V1 = V2, then Vo = 0. Otherwise, the output voltage obeys the relationships shown in **Figure 2B**, which is the transfer function of the comparator. According to the normal rules for operational amplifiers, making V1 larger than V2 causes the input voltage to look like a positive input to the inverting input, so the output potential is saturated at −Vsat, just below V−. Alternatively, when V1 is smaller than V2 the input voltage looks like a negative input potential, so the output is saturated at +Vsat just below V+. In **Figure 2B**, there's a small hysteresis band around zero where no output changes occur. This is an unfortunate defect in practical operational amplifiers.

The biased comparator

Figure 3A shows a method for biasing either comparator input to a specific reference voltage. This circuit is called a voltage level detector. Although in this case the noninverting input is biased and the inverting input is active, the roles can just as easily be reversed. Bias voltage V1 is found using the voltage divider equation:

$$VI = \frac{R2\ (V+)}{RI\ +\ R2} \qquad \textbf{(5)}$$

Figure 3B shows what happens when the noninverting input is biased to a positive voltage, V2. At time T1 the voltage applied to the inverting input (V1) begins to rise, but V1 < V2, so the output of the comparator is saturated to +Vsat. The V1 potential continues rising until time T2 when V1 = V2, so the output snaps toward zero; an instant later V1 > V2, so the output is saturated at −Vsat.

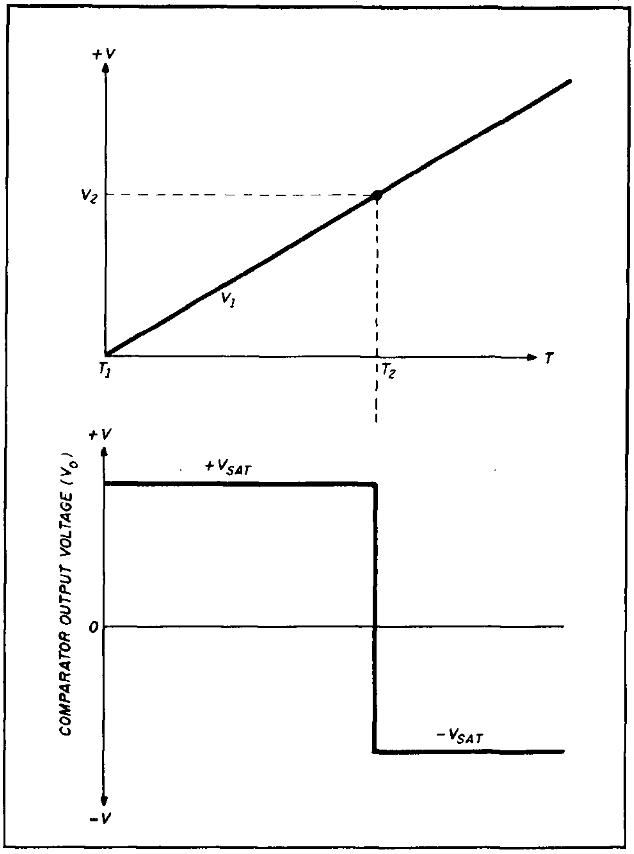
In the circuit presented in the section that follows, the noninverting input is biased through a resistor voltage divider, but the source potential is Vo. Thus, V2 will always be a fraction of Vo, and of the same polarity. That configuration (see **Figure 3C**) is sometimes called a Schmitt trigger.

Monostable multivibrator circuits

The monostable multivibrator (MMV) has two permissible output states (HIGH and LOW), but only one of them is stable. The MMV produces one output pulse in response to an input trigger signal (see **Figure 4**). The output pulse (Vo) has a duration, T, in which the output is in the quasi-stable state. The MMV is also known under several other names: one-shot, pulse generator, and pulse stretcher. The name "pulse stretcher" is derived from the fact that the output duration (T) is longer than the trigger pulse (T > Tc).

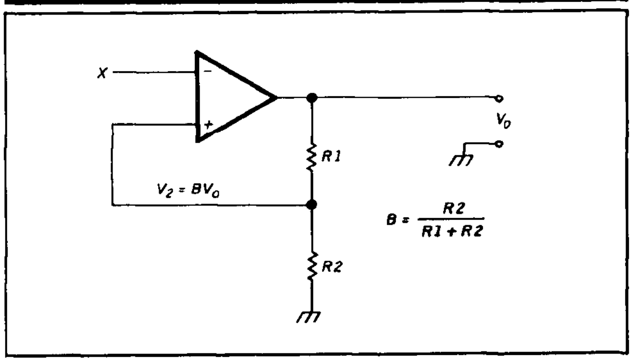
Monostable multivibrators have a wide variety of applications in electronic circuits. Besides the pulse stretcher, the MMV also serves to lock out unwanted pulses. **Photo**

FIGURE 3B



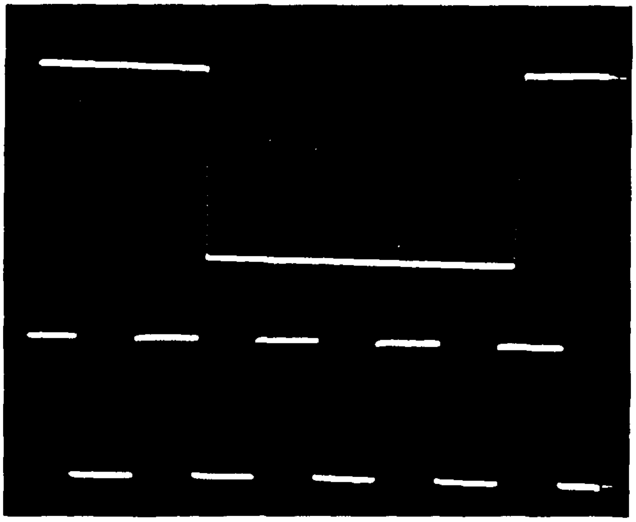
Graph illustrating the output of the comparator as the noninverting input is biased to a positive V2.

FIGURE 3C



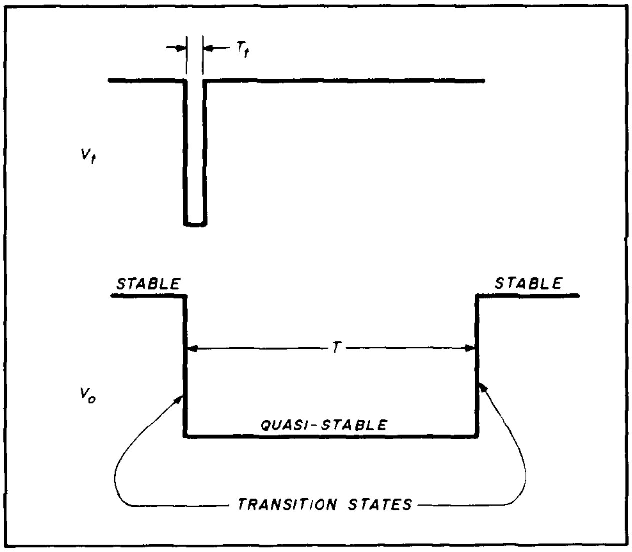
Basic schematic of a Schmitt trigger.

PHOTO A



The monostable multivibrator responds to only the first triggered input until the MMV is reset.

FIGURE 4



Output of a monostable multivibrator (one shot). Vt is the input trigger voltage and Vo is the output response.

A shows that the output responds to only the first trigger pulse. The next three pulses occur during the active time, T, so are ignored. Such an MMV is said to be "nonretriggerable." A common application of this feature is in switch contact debouncing. All mechanical switch contacts bounce a few times on closure, creating a short run of exponentially decaying pulses. If an MMV is triggered by the first pulse from the switch, and if the MMV remains quasi-active long enough for the bouncing to die out, then the MMV output signal becomes the debounced switch closure. The main requirement is that the MMV duration be longer than the switch contact bounce pulse train; 5 ms is generally considered adequate for most switch types.

Figure 5A shows the circuit for a nonretriggerable monostable multivibrator based on the operational amplifier. This circuit is based on the voltage comparator circuit discussed earlier. When there's no feedback, the effective voltage gain of an op amp is its open loop gain (Avol). When both −IN and +IN are at the same potential, the differential input voltage (Vid) is zero, so the output is also zero. But if V(−IN) doesn't equal V(+IN), the high gain of the amplifier forces the output to either its positive or negative saturation values. If V(−IN) > V(+IN), the op amp sees a positive differential input signal, so the output saturates at −Vsat. However, if V(−IN) < V(+IN), the amplifier sees a negative differential input signal, and the output saturates to +Vsat. The operation of the MMV depends on the relationship of V(−IN) and V(+IN).

There are four states of the monostable multivibrator that must be considered. They include the stable, transition, quasi-stable, and refractory states.

Stable state

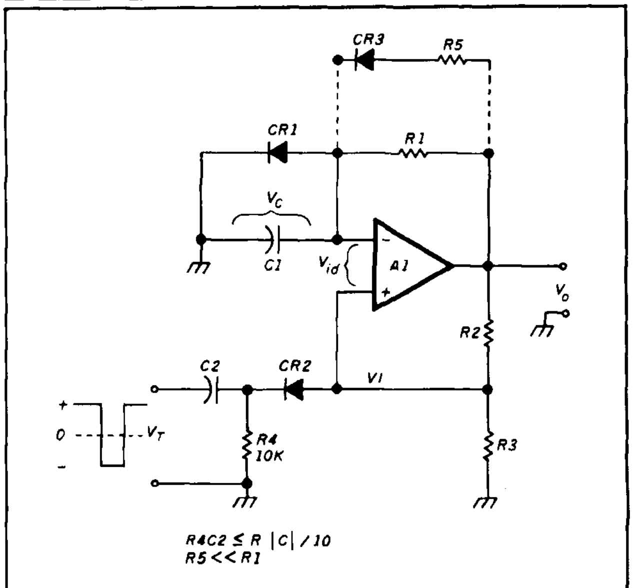
The output voltage Vo is initially at +Vsat. Capacitor C1 attempts to charge in the positive-going direction because +Vsat is applied to the R1C1 network. But because of diode CR1 shunted across C1, the voltage across C1 is clamped to +VCR1 (for a silicon diode like the 1N914 or 1N4148, +VCR1 is about +0.7 volts DC). Thus, the inverting input (−IN) is held to +0.7 volts DC during the stable state. The noninverting input (+IN) is biased to a level V1, which is:

$$V1 = \frac{R3\ (+Vsat)}{R2 + R3} \tag{6}$$

or, in the special case of R2 = R3:

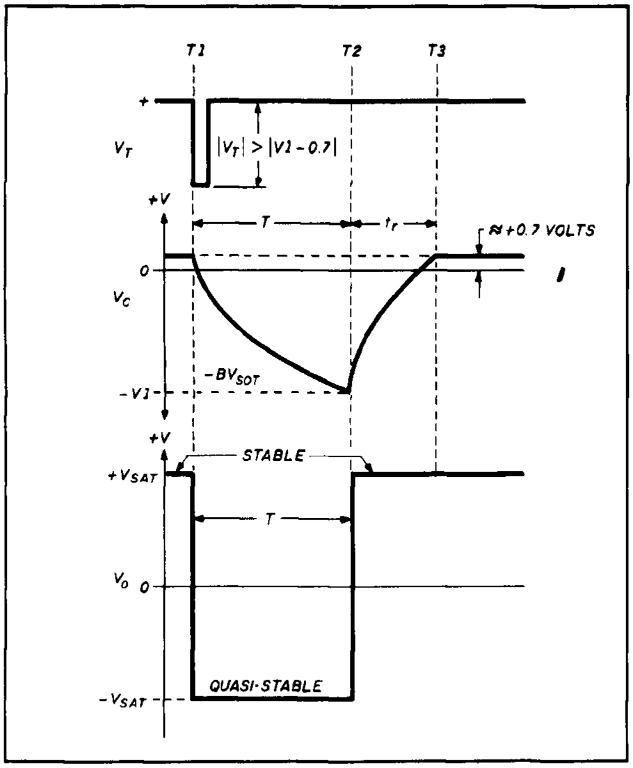
$$V1 = \frac{+Vsat}{2} \tag{7}$$

FIGURE 5A



Schematic of a non-retriggerable monostable multivibrator (one-shot).

FIGURE 5B



Graphical representation of the various voltages associated with the monostable multivibrator.

The amplifier (A1) sees a differential input voltage (Vid) of V1 − VCR1, or V1 − 0.7 volts:

$$Vid = \frac{R3(+Vsat)}{R2 + R3} - 0.7 \qquad \textbf{(8)}$$

As long as V1 > VCR1, the amplifier effectively sees a negative DC differential voltage at the inverting input, so (with its high open loop gain) Avol will remain saturated at +Vsat. For this discussion, the amplifier is a type 741 operated at DC power supply potentials of ±12 volts DC, so Vsat will be ±10 volts.

Transition state

The input trigger signal (Vt) is applied to the MMV of **Figure 5A** through RC network R4C2. The general design rule for this network is that its time constant should be no more than one-tenth the time constant of the timing network:

$$R4C2 < \frac{R1C1}{10} \qquad \textbf{(9)}$$

At time T1 (see **Figure 5B**) trigger signal Vt makes an abrupt HIGH to LOW transition to a peak value less than V1 − 0.7 volts. Under this condition, the polarity of Vid is reversed and the inverting input sees a positive voltage: V1 + Vt −0.7 < VCR1. The output voltage Vo now snaps rapidly to −Vsat. The fall time of the output signal is dependent upon the slew rate and the open-loop gain of the operational amplifier, A1.

Quasi-stable state

The output signal from the MMV is the quasi-stable state between T1 and T2 in **Figure 5B**. It's called "quasi-stable" because it doesn't change over T = T2 − T1. But when T expires, the MMV "times out," and Vo reverts to the stable state (+Vsat).

During the quasi-stable time, CR1 is reverse biased and capacitor C1 discharges from +0.7 volt DC to zero, and then recharges towards −Vsat. However, when −Vo reaches −V1, the value of Vid crosses zero, and that change forces Vo to snap once again to +Vsat.

Equation 4 makes it possible to derive the timing equation for the MMV. The timing capacitor must charge from an initial value (Vc1) to a final value (Vc2) in time T. What value of R1C1 will cause the required transitions? Consider the case R2 = R3 (V1 = 0.5 Vsat):

$$R1C1 = \frac{-T}{Ln\left[\dfrac{Vsat - Vc2}{Vsat - Vc1}\right]} \qquad \textbf{(10)}$$

$$R1C1 = \frac{-T}{Ln\left[\dfrac{Vsat - ((0.5)(Vsat + 0.7))}{Vsat - 0.7}\right]} \qquad \textbf{(11)}$$

and, for the case Vsat = 10 volts DC:

$$R1C1 = \frac{-T}{Ln\left[\dfrac{10\ V - ((0.5)(10 + 0.7))}{10\ V - 0.7\ volts}\right]} \qquad \textbf{(12)}$$

Thus,

$$T = 0.69R1C1 \qquad \textbf{(13)}$$

Equation 10 represents the special case in which B = 1/2 (i.e., R2 = R3). Although R2 = R3 may be the usual case for this class of circuit, R2 and R3 might not be equal in other cases. A more generalized expression is:

$$RC = Ln\left[\frac{1 + 0.7/Vsat}{1 - B}\right] \qquad \textbf{(14)}$$

In which:

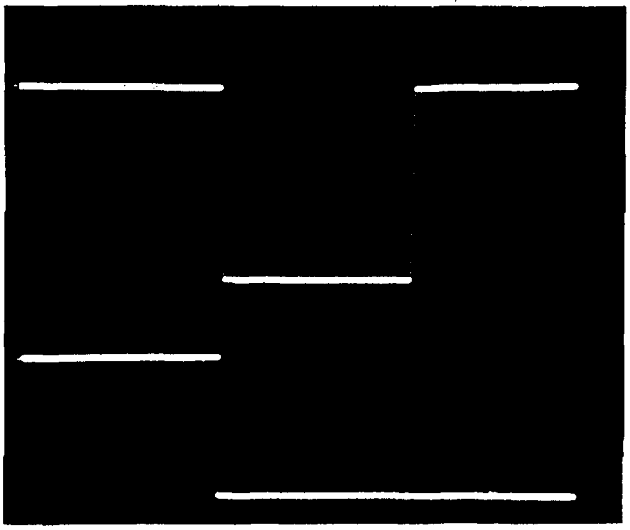
$$B = \frac{R3}{R2 + R3} \qquad \textbf{(15)}$$

When the quasi-stable state times out, the circuit status returns to the stable state, where it remains dormant until triggered again.

Refractory period

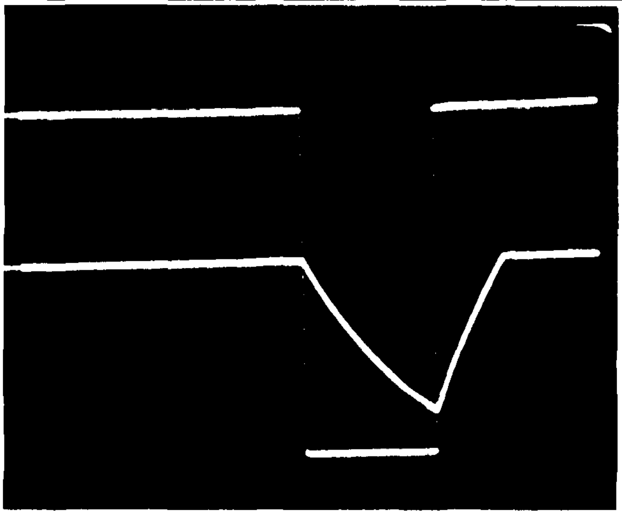
At time T2, the output signal voltage Vo switches from −Vsat to +Vsat. Although the output has timed out, the MMV isn't ready to accept another trigger pulse. The refractory state between T2 and T3 is characterized by the output being in the stable state, but the input is unable to accept a new trigger input stimulus. The refractory period must wait for the discharge of C1 under the influence of the output voltage to satisfy V1 < (V1 − 0.7 volts). In preparing this article, I built several MMV circuits using 741 op

PHOTO B



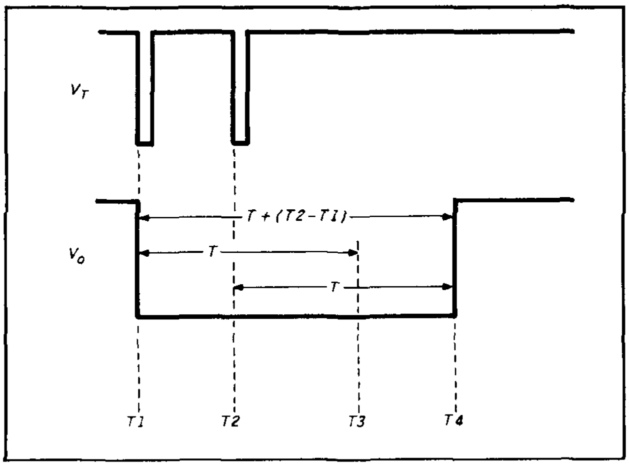
Top trace shows the output voltage (Vo) and the bottom trace shows the trigger voltage (Vt).

PHOTO C



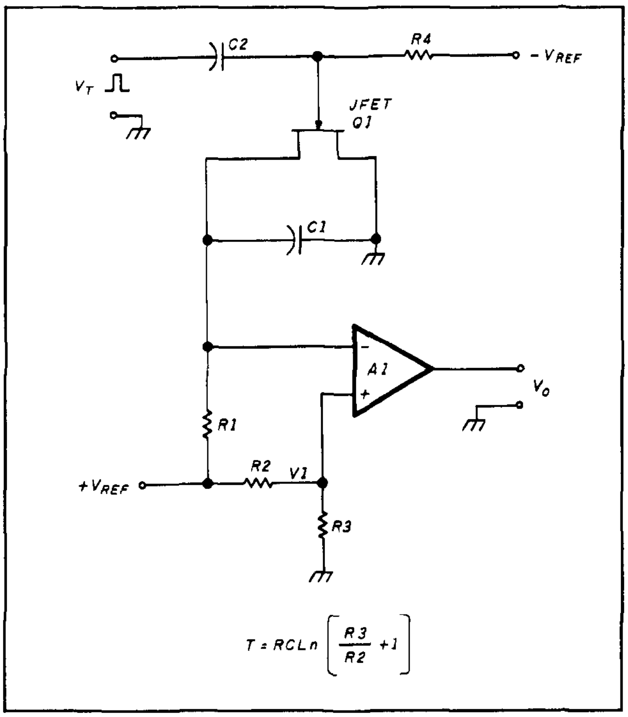
Vo is superimposed on the capacitor voltage (Vc).

FIGURE 6



Response of the retriggerable monostable multivibrator.

FIGURE 7A



Schematic of a basic retriggerable monostable multivibrator.

amps operated from ±12 volt DC power supplies. **Photo B** shows the output voltage (Vo) and trigger pulses (Vt). In **Photo C** the output pulse is superimposed on the capacitor voltage (Vc). The refractory period is shown as the increasing segment of Vc.

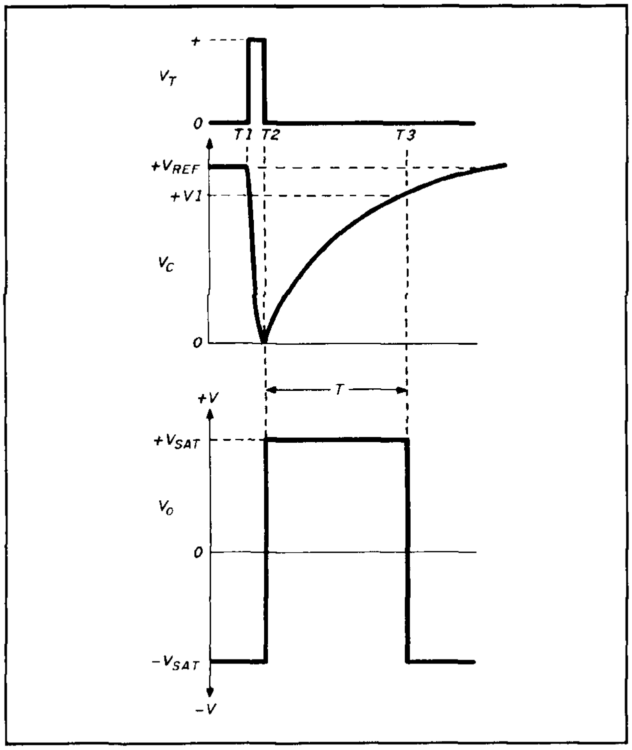
Retriggerable monostable multivibrators

The circuit in **Figure 5A** is a nonretriggerable MMV. Once it's triggered, the circuit won't respond to further trigger inputs until after both the quasi-stable and refractory states are completed. A retriggerable monostable multivibrator (RMMV) will respond to further trigger signals.

Figure 6 shows the response for the retriggerable MMV. An initial trigger signal (Vt) is received at time T1. The output snaps LOW and, under normal circumstances, would remain in this quasi-stable state until time T3, when the duration T expires. But at time T2, a second trigger pulse is received. The circuit is now retriggered for another duration T, so it won't time out until T4. The total time that the RMMV is in the quasi-stable state is [T + (T2 − T1)]. In other words, the RMMV output is active for the entire duration T, plus that portion of the previous active time which expired when the next trigger pulse was received.

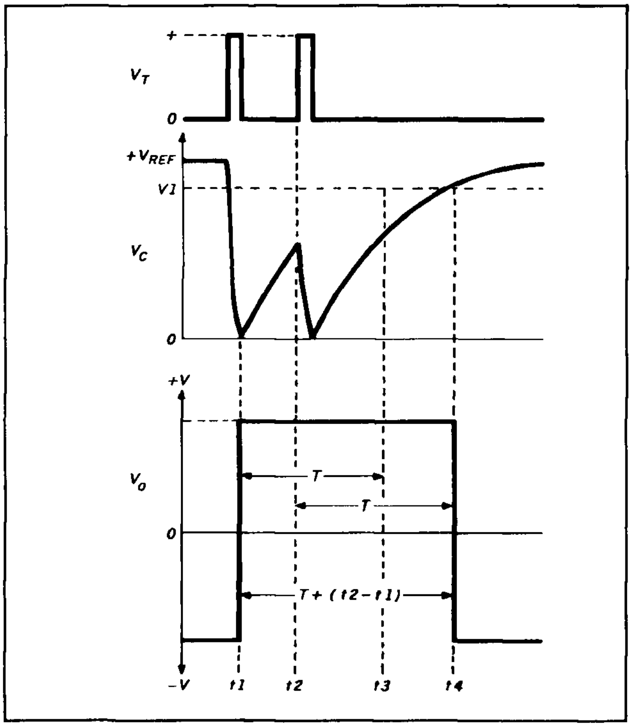
Figure 7A shows the circuit for a simple RMMV based

FIGURE 7B



Response graph of the non-retriggerable monostable multivibrator.

FIGURE 7C



Response graph of the retriggerable monostable multivibrator.

on an operational amplifier. The two inputs are biased from a reference voltage source, +Vref. The potential applied to +IN is a fraction of +Vref. That is, [(R3)(+Vref)/(R2 + R3)]. The potential applied to −IN is a function of +Vref and time constant R1C1. If the circuit isn't triggered at turn on, capacitor C1 charges up to +Vref, so −IN is more positive than +IN. This situation forces Vo to −Vsat, which is the stable state. When a positive-going trigger pulse (Vt) is received (see **Figure 7B**), it biases junction field effect transistor (JFET) Q1 hard on. The JFET drain source channel resistance drops very low, causing C1 to discharge rapidly between T1 and T2. With Vc close to 0 volts DC, +IN is more positive than −IN, so the output snaps abruptly to +Vsat at time T1. During the interval T2 to T3, capacitor C1 begins charging towards +Vref, and Vo remains at +Vsat. However, once Vc reaches +V1, the output of A1 snaps back to −Vsat.

The duration, T, is found from:

$$T = R1C1 \; Ln \left[\frac{R3}{R2} + 1 \right] \qquad \textbf{(16)}$$

The operation I just discussed, which is depicted in **Figure 7B**, is for normal nonretriggered operation. **Figure 7C** shows the retriggered case. Here the RMMV receives a second trigger pulse at time T2, which forces the JFET Q1 to turn on again, and rapidly discharge C1. The charging process then starts over again, and continues until the circuit times out — unless a further trigger pulse is received.

The RMMV is commonly used in alarm or sensing circuits. It's triggered by some external event, and will continually retrigger as long as that event keeps occurring. If no event is sensed prior to time-out, the RMMV returns to the stable state, and the following circuitry will be triggered to alarm status. For example, the timer MMV is retriggered every time a carrier drop is sensed. But if the same carrier stays on too long, the MMV "times out" and sends a signal to the circuit that turns off the transmitter for a short "rest period."

Part Two...

Now that you've had a refresher on RC networks, voltage comparators, and monostable multivibrators, it's time to move on to astable multivibrators. But, alas, the Editor's MMV "timed out" for this month, and we'll have to wait for part 2 to talk about the AMV circuit. hr

AN IMPROVED AGC CIRCUIT

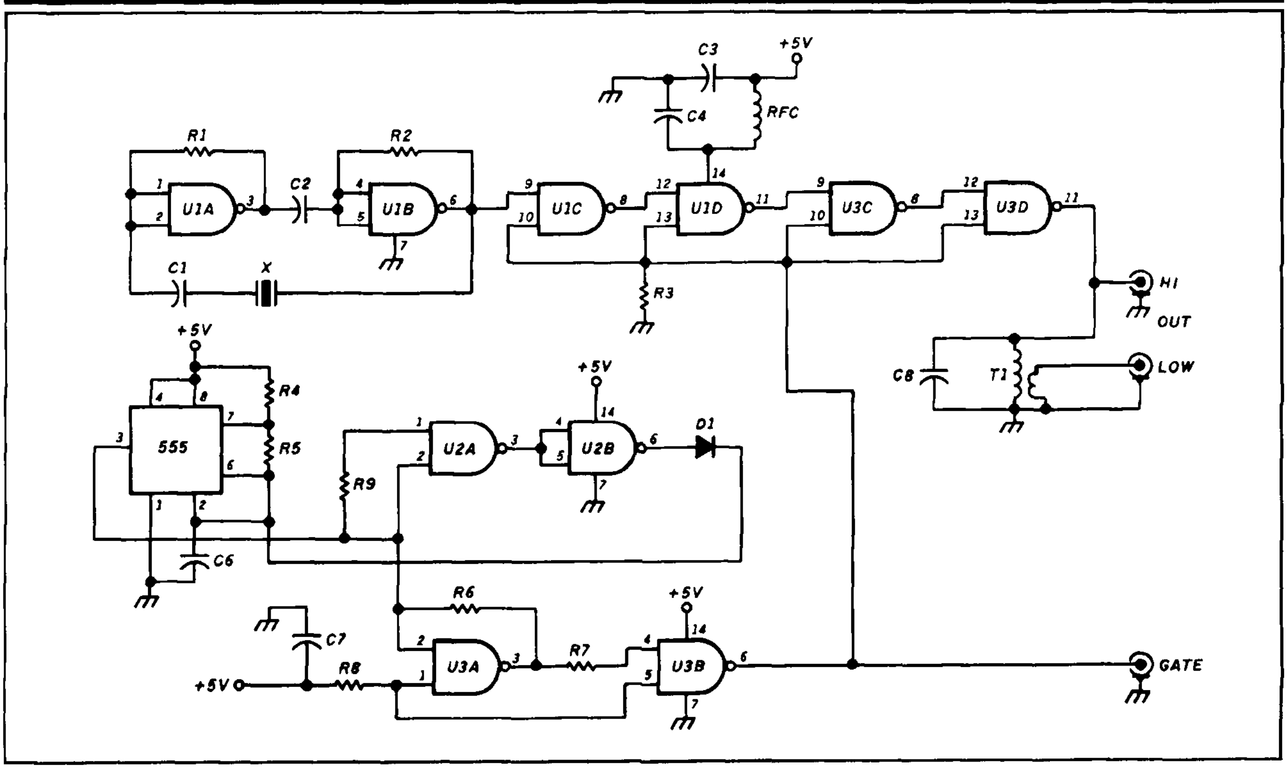
Add this circuit to your Kenwood TS-940S or TS-930S for DATA/RTTY reception

By W. C. Louden, W8WFH, 1915 Temblethurst Road, S. Euclid, Ohio 44121

Automatic gain control (AGC) circuits are used in receivers to adjust the gain of RF and IF amplifiers automatically. This prevents overdriving of the amplifier stages and maintains audio that's nearly constant with the varying strength of the input signal.

When propagation conditions are good, interference from

FIGURE 1



7.5-MHz pulse generator.

atmospheric noise is minimal, and adjacent channel chatter from other signals is low, any AGC circuitry will provide satisfactory results for most modes of reception. However, when fading is prevalent, or atmospheric noise increases due to summer electrical storms and adjacent channel chatter builds up, it's important to improve the design of the AGC system. While even a well-designed AGC system won't take the place of an effective noise blanker, it will supplement the blanker and let you receive information you'd lose in the presence of adverse conditions.

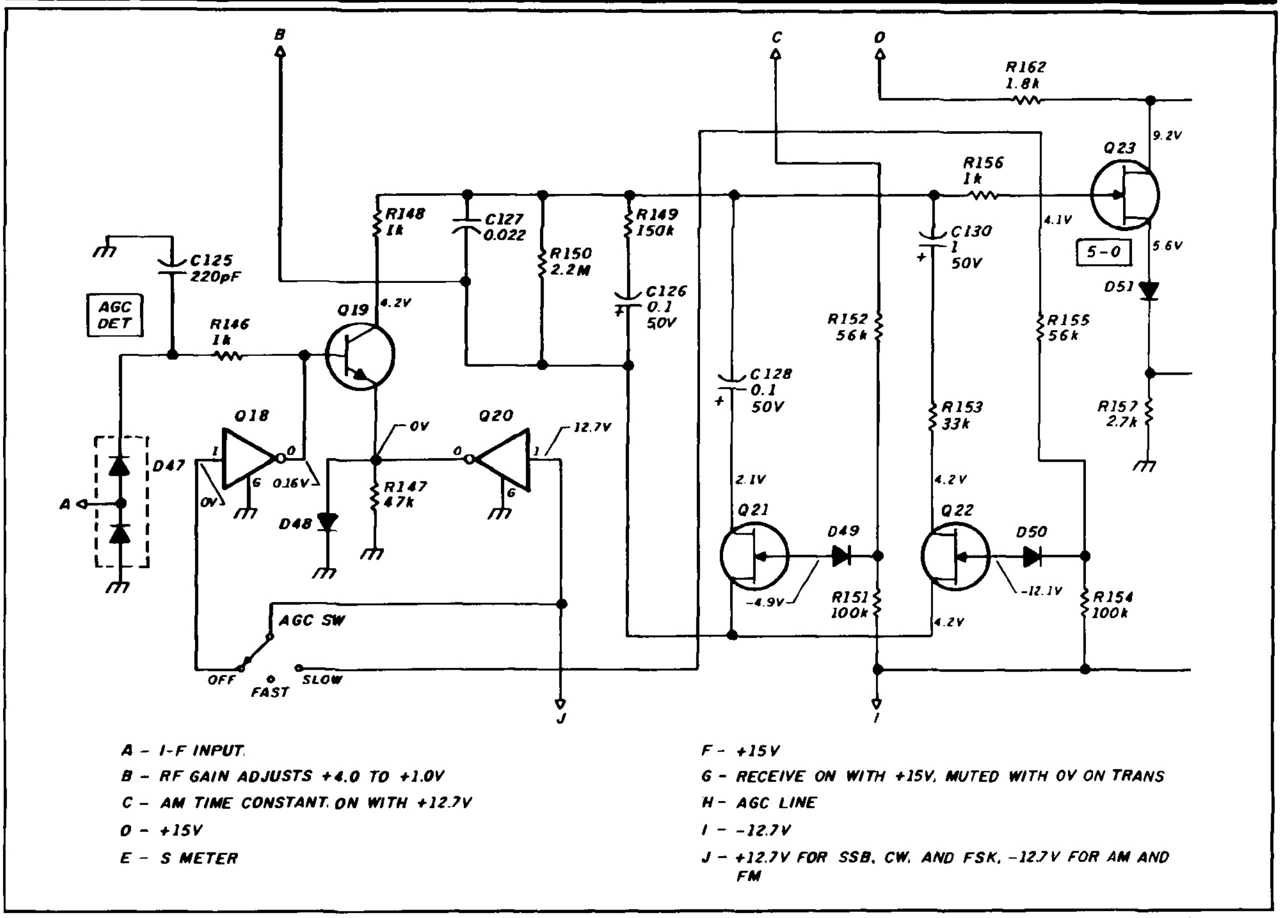
I realize that many of you may question the efficacy of changing an AGC system like the one in the TS-940S. Since the system doesn't generate any clicks or pops and works satisfactorily for SSB, AM, and CW, consider that changing it runs contrary to the old adage "If it ain't broke don't fix it." My question to you is: does it work well enough for data communications — RTTY, AMTOR, and packet? After a year or more of careful record keeping and diagnosis, I concluded the system wasn't effective enough. I found that nearly every case of an RTTY "hit" or error in the copy had occurred on days when there was static from electrical storms. The major portion of the static was in the form of short duration noise pulses. While you might expect that such static errors would result from the addition of bits of data, most of the hits were caused by a loss of bits. I determined this by referring to the *Teletypewriter Code and Garble Table*.

I found these hits puzzling. If the receiver was blanking on or after noise pulses, why couldn't the blanking action be heard as it occurred? I reasoned that if the blanking action was of short duration, it could be "seen" even though it couldn't be "heard." I connected an oscilloscope to the audio output, tuned the receiver to a vacant frequency and watched the static pulses. I saw nothing of significance until I inserted a data signal using the 100-kHz calibration standard. I tuned the receiver to obtain a 2300-Hz audio tone and synchronized the scope to the tone. As I watched a static pulse, I could see the noise peak. But there was a loss of audio information immediately following the peak which lasted from 4.5 to 12 ms, depending on the position

PARTS LIST

C1	20-pF silver mica
C2	0.001
C3,C4	0.01
C6	0.47 μF
C7	0.1
C8	33-pF silver mica
CR1	1N914
R1,R2,R3, R4,R8	1 k
R5	1.5 meg
R6,R7,R9	470
T1	primary—30 turns no. 24 on 1/2", OD toroid—Amidon T-50-2, secondary - 2 turns no. 24
U1,U2,U3	7400
Xtal	7.5-MHz crystal
RFC	220 μH

FIGURE 2



TS 940S AGC system.

of the AGC switch. I found that the "fast" position AGC was slower in recovering than the "slow" position.

The data loss period is made up of the sum of three time intervals. The first is due to the duration of the noise pulse. The second is the circuit group delay (the time it takes the AGC to start to react to the noise pulse), which is about 1 ms according to Rohde.[1] The third interval is the recovery time of the AGC. When the total of these three intervals is an appreciable part of the length of time it takes for a bit to be sent, the bit is lost. The duration of the noise pulse is an act of nature and, unfortunately, uncontrollable. The circuit group delay depends upon the number of resonators, and varies inversely with the bandwidth. It can't be changed without making sacrifices. But you *can* modify the AGC's recovery time.

Once I understood the problem, I listened closely to the receiver and noted that the lag in AGC recovery immediately following the static pulse caused a momentary quieting of the receiver. This, in turn, caused the loss of data bits. I decided that a reduction of the AGC's recovery time was required. It was necessary to come up with a reproducible test in order to work on the problem. I needed a test that would provide a pulse duplicating the effect of a static pulse on the receiver, so I wouldn't have to rely on electrical storms to measure my progress.

I devised the pulse generator shown in **Figure 1**. It has a 7.5-MHz crystal oscillator gated on for 2.5 ms at 2 Hz. The low pulse rate allows the AGC system to recover between pulses. None of the other parameters are critical.

The 7.5-MHz crystal came from my junkbox; the circuits are from *QST*[2] and *The 555 Timer Applications Sourcebook with Experiments*.[3] There's a broadly tuned circuit in the output which transforms the TTL voltage down to a usable value. I've provided outputs for the high and low level 7.5-MHz RF pulse and for the gate pulse. I built the generator on a Radio Shack perforated circuit board and mounted it in an aluminum box. I used a commercial 60-dB T pad attenuator with it to further reduce the generator low output.

The generator provided a calibrated "noise" pulse, similar to a static pulse in its effect on the receiver when connected to the antenna input. I observed considerable rounding off of the pulse envelope with the oscilloscope connected to the output of the 8.83-MHz, 455-kHz, and 100-kHz IF. This

FIGURE 2

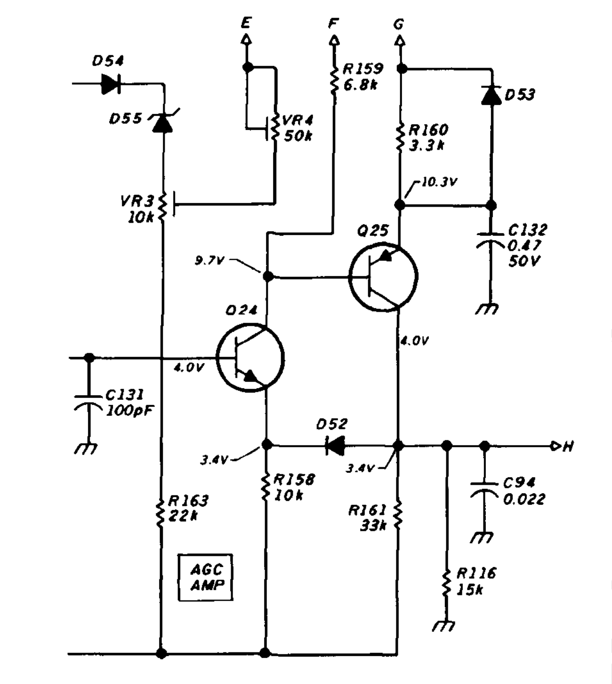


TABLE 1

TS-940S AGC circuits

Section	Components	Function
1	R148 (1.0 k)	attack and fast
	C127 (0.22 μF)	AGC circuit
	R149 (68 k)	
	C126 (0.1 μF)	
	R150 (2.2 meg)	Q19 load resistor
2	C128 (0.1 μF)	AM AGC time constant
3	C130 (1.0 μF)	slow AGC
	R153 (33 k)	
4	Q23 FET	AGC RC net isolation
	Q24	AGC amplifier/driver
	Q25	AGC line driver, T/R

is to be expected in any transceiver with a narrow bandwidth similar to the TS-940S.

After I made my preliminary observations, I decided to make some changes in the AGC circuit and get some on-the-air experience. Details of the TS-940S AGC circuitry (reprinted with permission from the *Kenwood Service Manual*) are shown in **Figure 2**. I've found it convenient to think of this part of the AGC system as being made up of four "sections" of related components. **Table 1** lists the key components used in the various sections, along with their nominal functions.

An incoming IF signal provided at A of **Figure 2** is rectified and doubled. A positive voltage is produced on the base of Q19. The voltage, which operates time constant sections 1, 2, and 3, comes from B and is established by setting the RF gain control. Current flows to Q19 through R148 and R150. When the AGC is turned on, the drive to the AGC system at A sets the Q19 base voltage. This, in combination with the voltage from B and the drop through R148 and R150, establishes the collector current through Q19. When Q19 is driven harder by the IF signal (including noise pulses) Q19's collector goes down, dropping the voltage at the junction of R148 and R150. This causes the AGC circuits to react and lowers the AGC voltage at H to affect the transceiver's gain. The attack and decay of that voltage is determined by the components of the three sections.

In section 1, the attack and fast AGC components are fixed. They function in parallel with the slow components of section 3 when FET Q22 is switched on in the slow AGC position by the application of +12.7 volts to R155. When the transceiver is switched to AM receive, +12.7 volts is applied to R152 at terminal C, toggling Q21 on and connecting C128 in parallel with section 1. Kenwood recommends the slow AGC (sections 1 and 3) for most operating modes except AM.

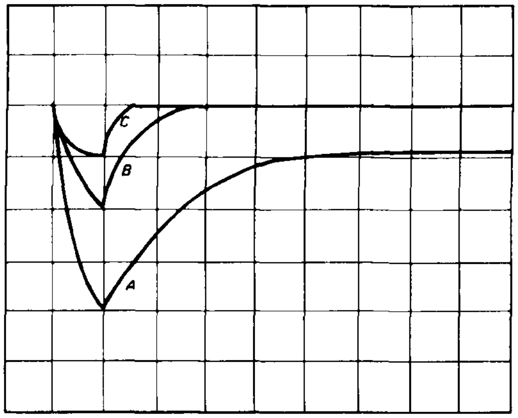
This entire circuit has other functions beside supplying the AGC bus voltage at terminal H. For example, when you adjust the manual RF gain control, the voltage at terminal B varies from +4.0 to +1.0 volts and establishes an operating voltage to the RF and IF stages through the **Figure 2** circuits. Also, when the transceiver is keyed to the transmit mode terminal G goes to 0 volts, reducing conduction through Q25, causing H to be driven to −4.0 volts, and cutting off the receiving RF and IF stages.

Using these observations as a starting point, I considered how I might approach the task of improving the data communications performance of the transceiver without altering the equipment's general circuit performance and original design concepts.

I isolated the AGC system from the RF and IF stages of the receiver by applying the square wave gating pulse (no RF) directly to the AGC input at the Q19 base. I used a 10-meg scope probe to prevent circuit loading. **Figure 3** shows how the original AGC system responds to the pulsed input as measured at terminal H. Under these test conditions (2.5 ms pulse at 2 Hz), the slow AGC position recovery time is less than that of the fast position. The longer the recovery time, the greater the probability that a bit of data will be lost.

These measurements don't include the time required for the IF stages to respond to the AGC voltage, so I also made measurements with the 7.5-MHz pulse applied to the receiver antenna. They indicated that the RF output of the 100-kHz fourth IF followed the curves in **Figure 3** closely. Test procedures maintained the signal below S9. Your operating procedures can also keep the input signal below S9 most of the time if you use the 30-dB input attenuator — an important part of the TS-940S.

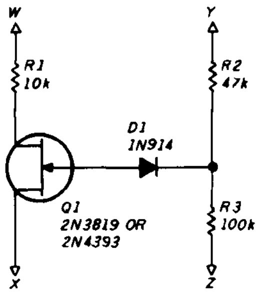
FIGURE 3



A - "FAST" AGC
B - "SLOW" AGC
C - NEW "FAST" AGC
HORIZONTAL SCALE = 2ms/DIV
VERTICAL SCALE = 0.5V/DIV
2.5ms SQUARE-WAVE PULSE at 2Hz APPLIED TO BASE OF Q19

Graphic display of oscillogram of AGC voltage developed with applied 2.5-ms pulse.

FIGURE 4



CONNECT	TO JUNCTION OF	
	TS-940S	TS-930S
W	R156 AND C130	R722 AND C510
X	R150 AND C126	R730 AND VR29
Y	AGC SW "FAST" CONTACT	
Z	R154 (-12.7V)	R738 (-12V)

New FAST AGC circuit for TS-940S and TS-930S.

In accordance with the design approach to reduce the AGC recovery time, I examined the RC time constants of section 1. Q19 load resistor R150 controls the recovery rate or discharge time for C127 and R149, the fast AGC circuit. Reducing the value of this resistor decreases the recovery time. I chose a value of 10 k. **Figure 3** shows the recovery time when it's paralleled with R150. When the AGC RF-IF amplifier loop circuit is closed, the amplitude of the AGC voltage tends to be normalized due to the gain of the loop, and curves A, B, and C fall on top of one another — except for the recovery times.

Before I go on, I'd like to note that I found an error in my

Kenwood Service Manual. The circuit diagram for the IF unit (X48-1430-00) doesn't agree with the pc board in my transceiver. The position of R150 was interchanged with R149 on the diagram in the manual. **Figure 2** in this article shows them correctly. Some serial numbers of the 940 show R149 changed from 150 k to 68 k.

You could change R150 to 10 k permanently but this would also affect the slow AGC, and that circuit is satisfactory for all other modes of operation. I used an approach *which didn't alter the original circuit* or circuit board. There's an unused contact on the AGC switch in the fast position (see **Figure 2**). I used this to actuate the circuit shown in **Figure 4**. I've included a table of connections for application to the TS-940S that you can make without removing the IF circuit board.

When you move the AGC switch to the fast position, the gate of switching FET Q1 is made positive and R1 is connected in parallel with R150. With the AGC switch in the slow position, the circuit is unaltered. Inserting a single pin connector in the Y lead lets you return the entire system to the original configuration by disconnecting that lead.

Construction and installation

The parts for the circuit in **Figure** 4 are mounted on a piece of Radio Shack circuit board slightly larger than a postage stamp. This is fastened to the IF unit with foam mounting tape.

Remove the bottom cover to access the IF unit, X48-1430-00. The location of every component is marked. You can make all connections to the IF unit on the exposed side of the board. Carefully clean the paint from the resistor leads and tack solder the wires of the new circuit to the exposed leads as indicated.

Remove the top and bottom covers to gain access to the contact on the AGC switch. Then remove two flat-head screws from each side of the front hinges so the front panel swings away from the chassis. Provide support for the front panel during this step to prevent damage to the panel or controls. Solder the wire lead Y shown in **Figure** 4 to the spare contact using a small iron and low heat. Use the TS-940S service manual to locate the IF unit and the component parts.

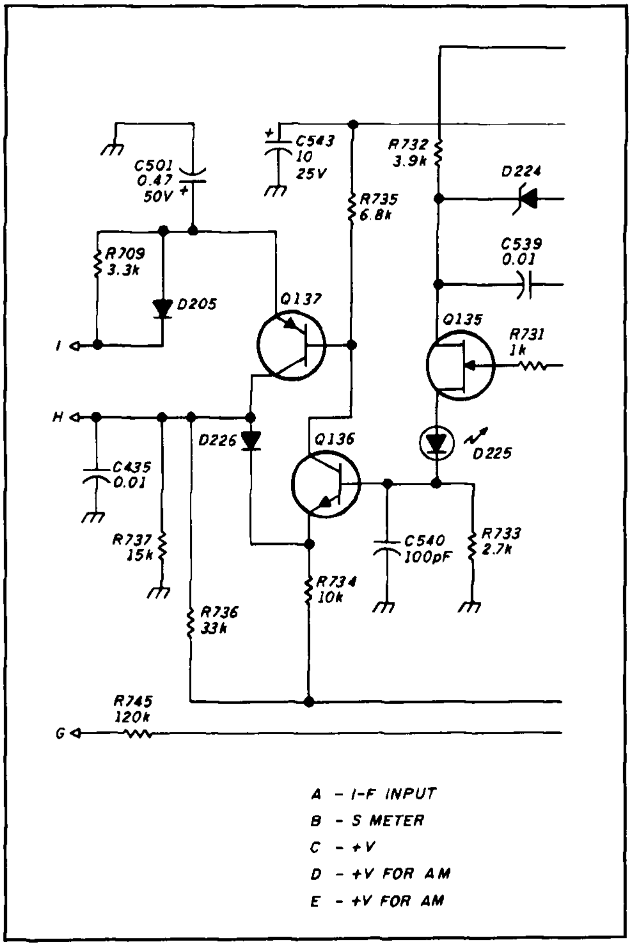
Recommendations for modifying the TS-930S

I did much of my initial work and record keeping with the TS-930S, before the TS-940S became available. As far as recovery time is concerned, I found the performances of the AGC systems much the same. The TS-930S AGC system may be modified using the same principles I used for the TS-940S. **Figure 5** is the TS-930S AGC system shown in the service manual. This system is very similar to the TS-940S. Operation is the same as that of the TS-940S and doesn't warrant additional explanation. The AGC switch is the same in the two models, so there is a spare blank contact available to operate the new fast AGC circuit. The table in **Figure** 4 shows the connections to the TS-930S for the new circuit.

On-the-air testing

Preliminary tests showed that the 8.83-MHz filter is "shock" excited to oscillation at its resonant frequency by the 7.5-MHz pulse applied to the receiver antenna. This lengthened the pulse and countered the short recovery time by increasing it. Oscillation occurs whether the slow AGC is on or the AGC is off; it just becomes more obvious with the new fast AGC. Static pulses act in the same manner to cause oscillation.

FIGURE 5



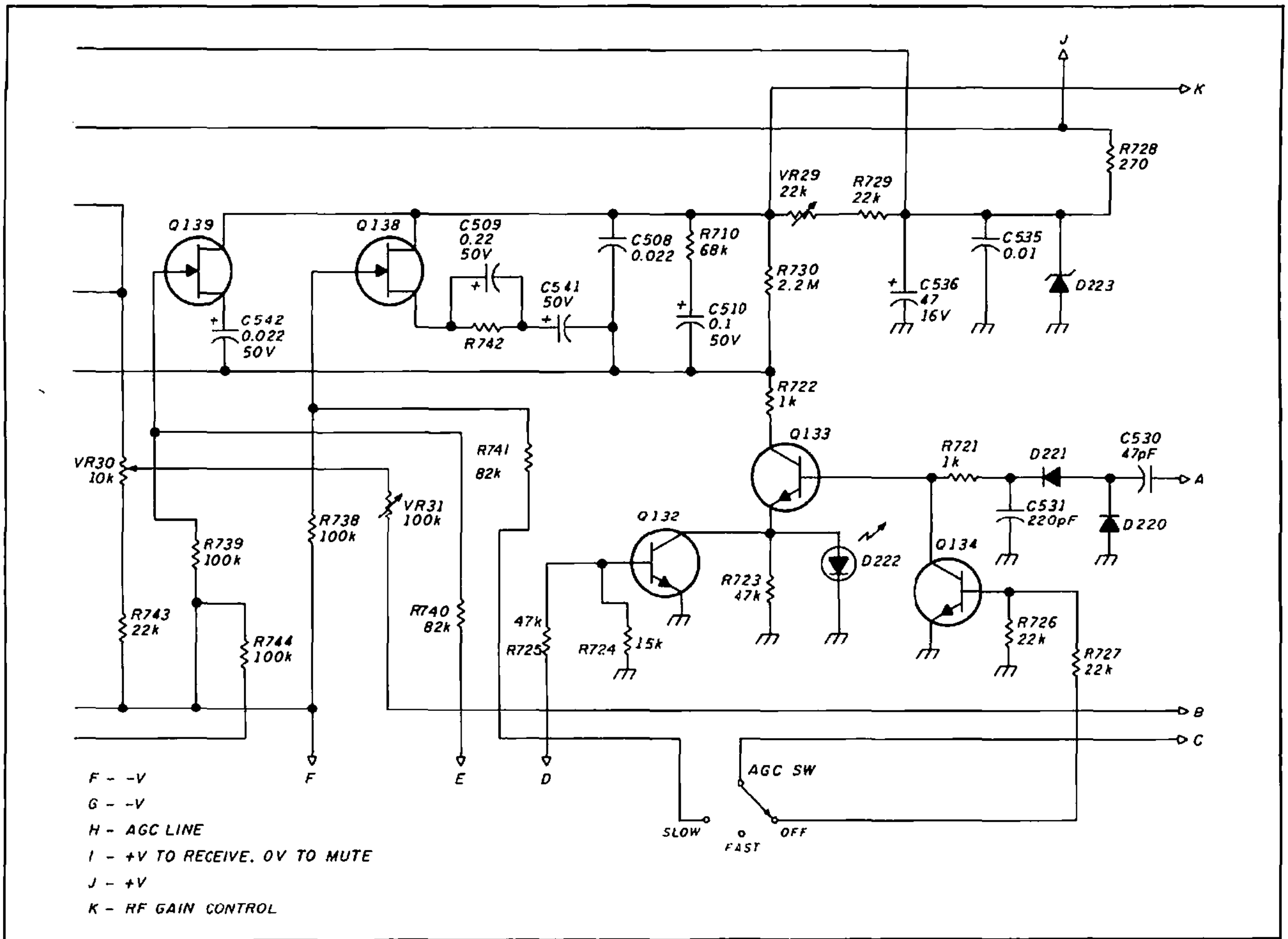
TS-930S AGC system.

I then investigated the noise blanker to determine if it would act to blank such pulses and prevent the oscillation from degrading the recovery time. (Noise blanking occurs before the 8.83-MHz filter.) NB2 was very effective in blanking the repetitive 7.5 MHz-pulse and in blanking similar single static pulses. Not all static was blanked, but not all static causes ringing. The noise blanker does act to prevent oscillation; set the level control between 0 and 2 for best results.

The slow AGC figure of merit, the change in audio output with increased signal strength,[4] is 0 dB for signal levels from 1.55 μV to 1.55 μV + 110 dB. The new fast AGC causes an increase of 3 dB for the same signal range. This isn't significant.

My RTTY reception improves dramatically when I use the new fast circuit during the noisy summer months. Fast fading effects are reduced — the circuit recovers fast enough to compensate. I do notice a raspy quality on voice communications. This isn't a problem on RTTY because the

FIGURE 5



signal is like a continuous carrier. When an adjacent SSB signal tends to control the AGC and prevent reception of the wanted on-channel signal, I can switch on the new fast AGC. This allows copy between voice peaks of the other signal, and generally works unless the other station turns on its voice processor. If conditions are good, I switch on the slow AGC for the best voice quality. However, the new fast AGC outperforms the slow one for DATA/RTTY reception.

Acknowledgments

I'd like to thank Allen P. Haase, W2ECA, and John A. Kiener, W8AVH, for their expert assistance in the preparation of this article. hr

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PRODUCT REVIEW

PC HF FACSIMILE VERSION 4.0

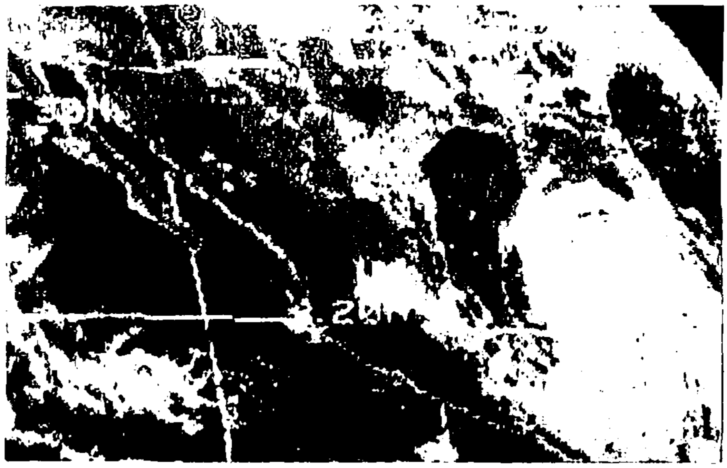
PC HF Facsimile Version 4.0 from Software Systems Consulting makes a nifty addition to your ham shack. It can be used for capturing Weather Fax and other Fax formats from the HF bands without any hardware but your MS-DOS compatible computer. John Hoot, N6NHP, has developed a software program that, with the aid of a simple analog to digital demodulator, can capture real time facsimile images using your computer's own power.

The minimum system requirements to run the PC FAX program are:

- MS-DOS compatable computer with 384K memory
- CGA, EGA, HGA, or VGA card and monitor
- One serial port
- Optional printer for hard copies
- MS-DOS Version 2.1, or higher
- A good HF receiver

The A/D demodulator has a 1/8-inch phone jack on one end that connects to the earphone or speaker output of your radio; the other end has a female DB25 connector, which is connected directly to the serial port of the PC. (The software supports either COM1 or COM2). You also get a cassette tape to help you recognize FAX signals and check out the PC FAX program.

The software will run from a floppy or can be installed on a hard disk. Either way, once you've loaded the program, the interactive menus make using the PC FAX program a snap. I first used PC FAX with a CGA card and monitor and was quite impressed. Later, I replaced my CGA system with an EGA card and monitor. It made a great difference — especially on the satellite photos.



The 80-page user's manual included in the package is well written and makes it easy to be up, running, and capturing your first image in less than a half hour. It was truly exciting when I got my reception system going the first time. Using the Autostart feature, which lets the program run unattended, was even better. The program can be configured to wait for a start tone, capture a frame, write the frame to disk, wait for the next frame, and so on.

The morning after I first used the Autostart feature, I reviewed the 12 frames captured from the previous night's operation. Among them I found a photo of the entire Earth taken with infrared sensors. It showed a newly formed tropical storm. Later that morning, the weather men announced its formation for the first time!

Once images are captured, they can be displayed in a variety of ways. Images can be viewed in color or 16 shades of grey (EGA or VGA), lightened or darkened, zoomed in on, or converted to PCX format files for editing by Paint programs or importing to many other programs, like desktop publishing.

For more information on PC FAX Facsimile Version 4.0, call or write John Hoot, N6NHP, at Software Systems Consulting, 1303 S. Ola Vista, San Clemente, California 92672. Phone (714)498-5784.

de N1GCF

S-COM 5K Repeater Controller

I'd been planning to buy an S-COM 5K Repeater Controller ever since my friend Joel, WA1ZYX, got one for his 443.800 repeater.

Once I saw Joel's 5K, I couldn't wait to order my own. It finally arrived, and I opened the box with great anticipation. One box contained the new display rack-mount cabinet with 5K controller (vl. 3, S/N 681) and the audio delay module mounted inside it, one RS232 connector 25P male plug and hood, and the power connector to provide +12 to 15 volts to the cabinet. The second box held a custom 3-ring notebook with documentation on the 5K, schematics, and instructions for hooking the 5K controller to three different repeaters (more in the making I understand). It also had information using the 5K as a beacon and a circuit for positive voltage TX keying.

The front display rack-mount panel (1-3/4" × 19") is covered in chip-resistant black anodized paint. There are twelve red Hewlett-Packard AlGaAs LEDs to track important circuit status data like receiver COR (RX), transmitter PTT (TX), CTCSS decoder (PL), control receiver COR (CT), DTMF data valid (DV), power on (ON), logic inputs 1, 2, and 3 (I1, I2, I3), and logic outputs 1, 2, and 3 (O1, O2, O3). These LEDs feature high light output while consuming only 1 mA each, which makes them perfect for natural power sites. Should you experience a power failure, all data except time and date is saved in non-volatile memory.

A conductive iridium-plated chassis box reduces RFI and houses the 5K board, display board, and audio delay module. I removed the six metal screws and took a look inside. The audio delay board is mounted to the lid of the box, the 5K board on the bottom, and the display module on the front panel. The two boards and the module are connected by ribbon cables and connectors. A DB25S input/output connector (female) and a 2.5-mm DC power jack are mounted on the rear of the 5K board and project through the back of the chassis box. The power input has a Tranzorb™ suppressor and a ferrite bead, there are bypass capacitors on all inputs and outputs, and all power MOSFETS (logic outputs) have Transzorbs connected to them.

All the commands can be implemented without a lot work. Take Send ID, for instance. 99 55 * causes the ID to come on. In this case it's "ID" because I haven't programmed my callsign in yet. (The 5K is good, but not that good.) 99 11 * causes the next message to be sent at a slow rate — default, 15 wpm. The normal rate is 20 wpm. Both can be changed. A page in the CW section gives every letter and number a number code; each punctuation mark and CW speed is also assigned a number. Each com-

(Continued on page 84.)

mand must be followed by the * (star) key for it to be accepted. If you don't like using the *, you can program the 5K to accept the commands upon loss of COR or within a specified period of time after COR release.

The 5K can handle up to 200 macros in memory. This is probably more than eough for any repeater use. It can also handle up to 32 commands in a macro chain. Since N1BAC/R is part of the New England 220 MHz Network, I plan to let the 5K do all the switching, PTT of the linking system, timing, and IDing.

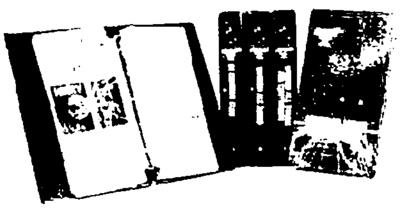
The S-COM 5K Repeater Controller, wired and tested, is priced at $195 plus $5 shipping and handling. The plain rack cabinet (1-3/4" × 19") is $35, audio delay module is $79 (add $3 for shipping and handling without others). The display cabinet runs $69 plus $5 shipping and handling without the 5K board. Extra manuals are available for $20. Contact S-COM Industries, P.O. Box 1718, Loveland, Colorado 80539-1718. Phone (303)663-6000.

de N1BAC

NEW PRODUCTS

Azimuth Awards QSL Library

Azimuth Communications Corporation has a new Azimuth Awards QSL Library for organizing and protecting your QSL cards. You can select an album for each award — DX Century Club, Worked All Zones, Worked All States, and Worked All Continents — or for your QSLs in general.



Each album is made of durable vinyl and comes with 20 scratch resistant pages, enough for 120 cards. The pocket pages hold six large 4 × 6 inch cards. Extra pages are available in packs of 20.

The cost, with Azimuth's special introductory offer, is $19.95 — a savings of $5 off the regular retail price of $24.95. Extra 20-page packs are just $12.95. Please add $2.50 shipping and handling per album and page pack (foreign orders add $US 7.50). California residents please add sales tax. To order contact: Azimuth Awards QSL Library Department EJ, 11845 W. Olympic Boulevard, Suite 1100, Los Angeles, California 90064.

Circle #301 on Reader Service Card.

IC-2500A Dual Band FM Transceiver

ICOM announces the new IC-2500A dual band FM transceiver, equipped with both 440 and 1200 MHz. It features:

- Two bands in one transceiver. The IC-2500A simultaneously covers 440 to 450 MHz and 1240 to 1300 MHz.
- Cross band full duplex.
- Simultaneous dual band watch. The IC-2500A can receive on both the main and sub bands at the same time.
- AFC and RIT functions.
- 40 memory channels plus two programable call channels.
- Scan functions and priority watch.
- High power output. The IC-2500A provides a full 35 watts output on high power for 440 MHz and full 10 watts on 1200 MHz.
- Independent squelch and volume.

The optional UT-40 tone squelch unit is a pocket beep function that lets you make contact with only those stations you wish.

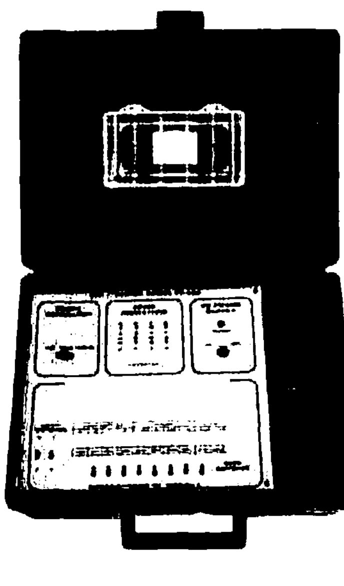
The IC-2500A dual band FM transceiver is priced at $999. Contact ICOM America, Inc., 2380 116th Avenue N.E., PO Box C-90029, Bellevue, Washington 98009-9029. Phone (206)454-8155.

Circle #302 on Reader Service Card.

XK-220 Digital Trainer

The Elenco digital trainer model XK-220 is designed for the student or hobbiest who wants hands-on training in the workings of digital theory.

Circuits are easily assembled on the 590-pin breadblock and 100-pin breadstix. The trainer has three power supplies, eight data switches, two logic switches, and eight logic indicators.



The unit has a sturdy carrying case with a parts box in the lid. The XX-220 comes complete with instructions and circuit descriptions. You supply ICSs, wire, and circuit diagrams.

The trainer is also available in kit form with easy-to-follow instructions and a troubleshooting guide. The assembled XK-220 costs $150, the kit is $110. Contact Elenco Electronics, Inc., 150 W. Carpenter Avenue, Wheeling, Illinois 60090. Phone (312)541-3800.

Circle #303 on Reader Service Card.

Kantronics Superfax II

Kantronics, Inc. announces the Superfax II. Superfax II requires the use of a Kantronics TNC using version 2.8 or later firmware. It features:

- Unattended mode
- Semi-unattended mode
- Manual mode.
- View from buffer or disk file, with the ability to pause display.
- Display black on white or white on black.
- Save buffer to disk, saves all scan lines.
- Print picture black on white or white on black.
- Choose 120 lpm for weather facsimile or 60 lpm for wire photo pictures.
- All scan lines are saved; however, you can choose to receive the full width of the picture including sync lines, or receive 80 or 66-percent width of picture.
- Split-screen terminal mode non-buffered keyboard input characters are sent immediately to TNC capture incoming data to disk.
- Supports CGA, EGA, VGA/MCGA and HERCULES™, also some graphics modes of the Olivetti™ and AT&T™ personal computers.
- Supports com1, com2, com3, and com4.
- Prints to printers with Epson compatible graphics modes, or use the custom setup to configure for most nine-pin graphics capable printers.
- Requires Kantronics TNC using version 2.8 or later firmware.

Superfax II is priced at $29.95 and is available from Kantronics, Inc. 1202 E. 23rd Street, Lawrence, Kansas 66046. Phone: (913)842-7745.

Circle #304 on Reader Service Card.

MEASURING THE ACCURACY OF A PARABOLIC ANTENNA

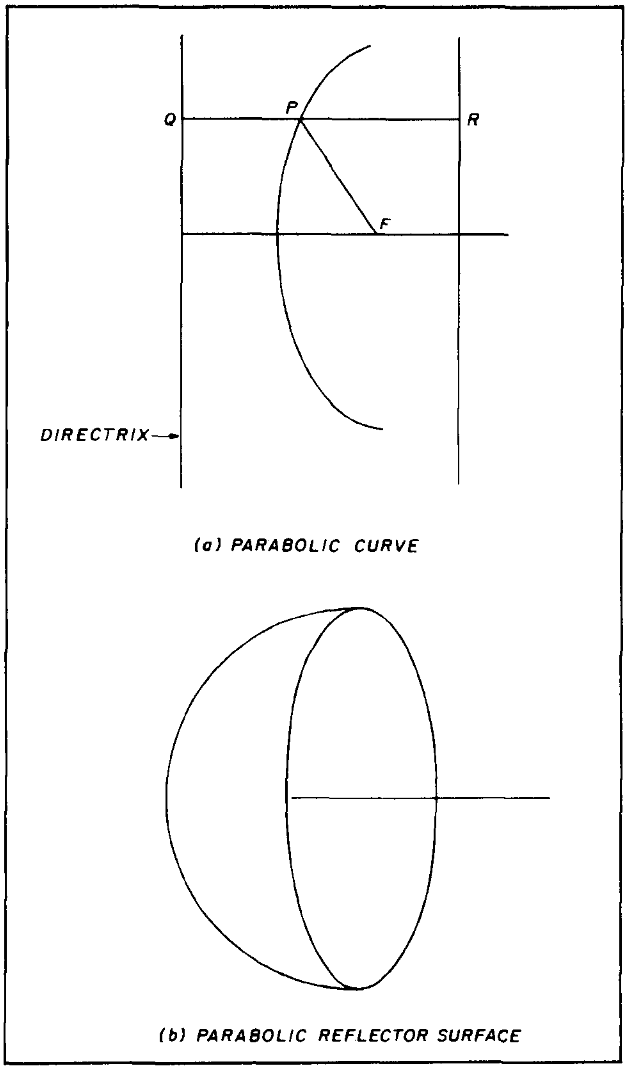
By Lester A. Wagner, WA8BJO, 463 S. Tecumseh Road, Springfield, Ohio 45506 and Glen Grewell, W8FP, 251 Estelle Avenue, Enon, Ohio 45323

The parabolic antenna is a useful design when you consider the use of the higher frequency bands and the increased interest in satellite TV and Amateur Radio reception. This type of antenna offers higher gain than other conventional antennas. Also, when you look at the fairly high cost of commercial dish antennas, a homebrew parabolic antenna seems more practical, if not a necessity for the Radio Amateur. You can make the reflector out of a mesh or screen at frequencies in the range of 1 to 5 GHz. Because a parabola isn't a simple shape like a circle or a flat plate, you'll find you have some difficulty measuring the shape of the surface. This article describes a simple method of measuring the surface of a parabolic reflector. We used a BASIC computer program to calculate the parameters necessary to determine the accuracy of the surface. We constructed a special measuring rod to ascertain, from the focus, the distance of points on the surface as determined by the computer program. This method of accuracy determination eliminates the need for a large template, which is difficult to use because of its size.

The parabolic surface

The parabolic reflector is probably the most widely used high-gain antenna. Reflecting antennas achieve gains in excess of 30 dB in the microwave region. The simplest reflector consists of two components — a large reflection surface and a much smaller feed source. According to the definition of the parabolic curve in **Figure 1A**, the distance from any point P on the parabolic curve to the focus is equal to the perpendicular distance from that point to a line called the directrix. The directrix is a line perpendicular to the axis, passing through the point which is the virtual image of the focus. Thus, in **Figure 1A**, PF = PQ. The parabolic reflector has a very unique property: all the waves originating from a point source at the focus arrive at a line perpendicular to the axis with equal phase. A parabolic surface is formed by rotating the top half of the curve in **Figure 1A** around the axis forming the surface as shown in **Figure 1B**.

FIGURE 1



Parabolic reflector antenna: (A) parabolic curve, (B) parabolic reflector surface.

TABLE 1

Parameters for measuring the parabolic antenna surface. (Dimensions are in inches.)

S	L
0	58.91
2	58.93
4	58.98
6	59.06
8	59.18
10	59.33
12	59.52
14	59.74
16	59.99
18	60.28
20	60.59
22	60.95
24	61.33
26	61.74
28	62.19
30	62.67
32	63.18
34	63.72
36	64.29
38	64.89
40	65.51
42	66.17
44	66.86
46	67.57
48	68.31
50	69.08
52	69.87
54	70.69
56	71.54
58	72.41
60	73.31
62	74.23
64	75.17
66	76.14
68	77.12
70	78.14
72	79.17
74	80.22
76	81.29

The parameters which define the parabolic surface are somewhat difficult to measure. You can solve this measurement problem by defining two other measurable parameters.

We decided that determining the parameters of S and L would make surface measurement easy. These dimensions are defined in **Figure 2**. Length S is the straight line distance from the center of the parabola to the point on the surface to be measured. Length L is the distance from the focal point to a specific point on the surface of the parabola. Note that distance L isn't a simple constant radius. Distance L from the focus increases as distance S from the center of the parabola increases.

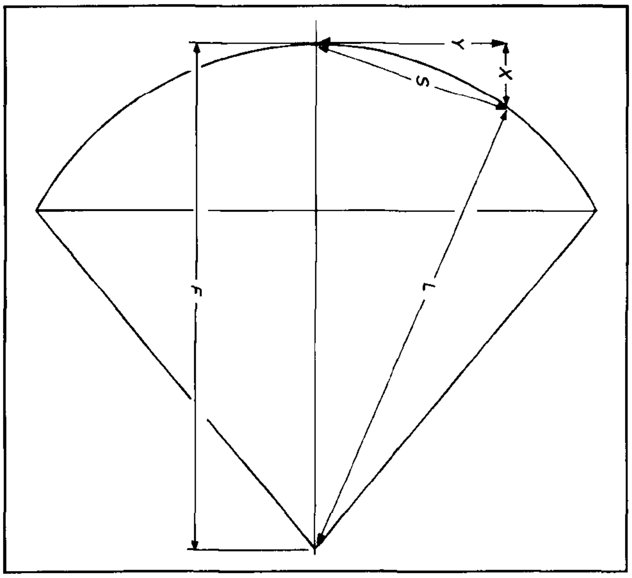
We determined parameters S and L for a 12-foot diameter parabolic antenna with a 58.9-inch focal length. We calculated value L for each 2-inch increment in distance S. We chose these dimensions because they were easy to measure. **Table 1** shows the values for S and L in inches. The simple BASIC computer program used to calculate these values is given in the appendix so that you can compute the parameters for larger or smaller dish antennas.

The measuring element

The 12-foot diameter parabolic antenna with a focal length of 58.91 inches shown in **Figure 2** was built to receive satellite signals in the 4-GHz frequency range. The frame for the antenna was constructed from thin wall 1/2-inch conduit welded together. The conduit frame was covered with coated steel insect screening to form the parabolic reflector surface. The technique developed here is used to determine the accuracy of the surface.

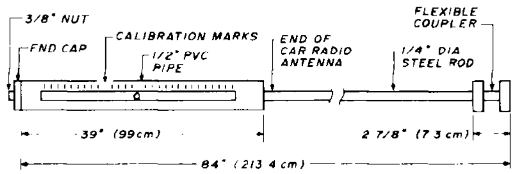
As mentioned before, we designed a special measuring element to find distance L. The device is shown in **Figure 3**. Our design makes it easy to adjust its length. We built this measuring rod primarily from parts found in our junkboxes. We used the following parts: a 39-inch length of 1/2-inch diameter PVC pipe, part of a telescoping car antenna, a flexible coupler, and a piece of 1/4-inch metal rod 35 inches long. First we cut a 1/8-inch wide, 30-inch long slot in one wall of the PVC pipe (see **Figure 3**). This slot permits the pointer to slide back and forth, indicating the total length of the measuring rod. The internal part of the device is made from the 1/4-inch rod, the telescoping antenna section, and the end cap. We connected the end cap to one end of the telescoping section. Then we attached the end cap to one end of the PVC pipe. We then fastened the other end of the telescoping section to one end of the 1/4-inch rod and soldered a short pointer to the junction of the rod and the telescoping section. The pointer can stick up out of the slot in the PVC pipe and slide back and forth as the rod is extended and shortened. We inserted the extendable rod assembly into the PVC pipe until the end cap fit

FIGURE 2



Basic geometry of a parabola.

FIGURE 3



Measuring rod.

onto the end of the pipe. **Figure 3** shows the final assembly of the measuring rod. We put calibration marks on the outside of the PVC pipe to indicate the length of the rod assembly. These marks show the total length of the measuring rod, making it easy to use. You must be able to extend the measuring device from approximately 58 to 82 inches in length in order to measure the distance to any point on the parabolic surface.

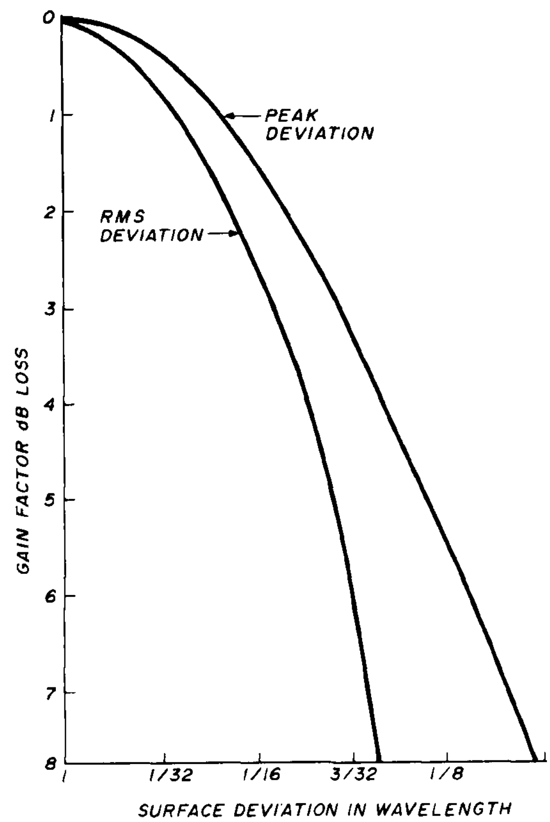
We used our measuring rod to calculate the accuracy of the parabolic surface of our antenna. First, we removed the low noise amplifier (LNA) from the antenna feed. Next, we attached a connector, which mates with the connector on the flexible couple on the end of the measuring rod, to the end of the pipe that holds the LNA in place. Then we loosened the clamps holding the piece of pipe, slid the pipe toward the parabolic dish until the connector was at the focal point, and tightened the clamps to hold the pipe in place. Fastening the flexible coupler on the measuring rod to the connector on the pipe was the next step. This holds one end of the measuring rod at the focal point, leaving the other end free to be placed at any point on the surface of the parabola. You can read distance L directly from the calibrations on the measuring rod when you slide the end of the measuring rod to a point on the parabola. The most accurate position for antenna measurement is a horizontal one; that is, with the antenna pointed at the zenith.

Effect of surface accuracy on performance

You may wonder how accurate the surface of a parabolic reflector antenna should be and why this accuracy is important. The accuracy of the reflector surface is important because it indicates the specifications to which the antenna must be built; it also gives an indication of the antenna's gain reduction. The surface roughness causes phase distortions in the reflected energy and this can reduce the overall antenna gain. The phase error (which can be tolerated because of surface roughness) is directly proportional to the frequency. Larger surface errors can be better tolerated at lower frequencies than at the higher ones. Ruze provides a mathematical expression which relates the surface tolerance to a reduction in gain. Deviation from the true surface can be expressed in peak deviation or in RMS deviation. The graph in **Figure 4** shows the reduction of gain as a function of surface error. One curve is for peak deviation from the surface; the other is for the RMS deviation from the surface. For a peak deviation of 1/16 wavelength, the reduction in gain is approximately 1.5 dB; for an RMS deviation of 1/16 wavelength, the reduction is approximately 2.7 dB. The loss in antenna gain quickly increases as the surface error exceeds 1/16 wavelength RMS. Surface irregularities are caused by construction errors and external forces acting on the structure. As the frequency at which the antenna is used increases, the tolerances of the parabola become tighter. For example, a 1/16 wavelength is 0.55 inches at 1296 MHz, 0.32 inches at 2300 MHz and 0.18 inches at 4000 MHz.

Any corrections you make to the surface must be made in terms of the frame, because the surface is made of window screen. Make sure all the spokes are well fitted to the center plate. The spokes should be laid out and bent into shape before you attach them to the center plate. Once you've connected them to the center plate, check to make sure that each spoke has the correct shape. You can use the measuring element to measure points on the spokes. If the position is off, bend the spoke to bring the point into line. Changing the frame is a tedious process because bending the frame to change one point may affect other points on the frame. The measuring element lets you determine the accuracy of different points on the frame. You'll find this much easier than holding a 12-foot template in place to measure several points. The measuring and bend-

FIGURE 4



Reduction of gain due to surface errors.

ing procedure is an iterative process; repeat it until the surface's accuracy is acceptable. Our antenna's surface is within ±1/8 inch tolerance.

Conclusions

We've provided a simple method for determining the accuracy of the parabolic surface and for calculating the parameters used to check the surface accuracy. The parameters given here are for a 12-foot diameter parabolic antenna with a 58.91-inch focal length; however, you can change the computer program's parameters easily to provide data for checking parabolic antennas of other sizes. The BASIC program is written for a Commodore 64 computer, but can be applied to other home computers and programmable calculators. With increased accuracy, your parabolic antenna will provide better performance than other types of antennas at the higher frequencies.

Appendix

The surface of a paraboloid is described by the equation:

$$Y^2 = 4\,FX \tag{1}$$

where F is the focal length of the parabola.

To simplify surface measurement, determine the parameters of S and L. These dimensions are defined in **Figure 2**. Values X and Y are the rectangular coordinates of the points on the paraboloid.

Use the following procedure to calculate distance L (see **Figure 2**). The distance S is given in terms of F, X, and Y as:

$$S = \sqrt{X^2 + Y^2} = \sqrt{X^2 + 4FX} \tag{2}$$

By using **Equation 2** and applying the quadratic equation from algebra, you can solve for X as:

$$X = \sqrt{4F^2 + S^2} - 2F \tag{3}$$

Once you've determined X, you can find distance L using the Pythagorean theorem as in **Equation 4**:

$$L = \sqrt{Y^2 + (F-X)^2} = \sqrt{4FX + (F-X)^2} \tag{4}$$

With a specific distance S, you can calculate distance L by using the focal length. Distance L is the same for all points located at a specific distance from the center of the parabola. This describes a locus of points which fall in a circle on the parabola's surface.

We've included a listing of the computer program to calculate the parameters used in the measurements. We wrote the program to obtain the values in **Table** 1 in BASIC for use on a C-64 computer. You can use this program to compute the parameters for dish antennas of different sizes.

BASIC COMPUTER PROGRAM

```
10 F= 58.909
20 FOR S= 0 TO 76 STEP 2
30 X=SQR(4*F*F+S*S)-2*F
40 L=SQR(4*F*X+(F-X)*(F-X))
50 PRINT S,L
60 NEXT S
70 END
```

where:

F is the focal length of the parabola,

L is the distance from the focus to the point on the parabola, and

S is the distance from the center of the parabola to the point of concern on the parabola.

REFERENCES

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2. J.D. Kraus, *Radio Astronomy*, 2nd Edition, Cygnus-Quasar Books, Powell, Ohio, 1986, pages 6-57 through 6-62.
3. G.L. Hall, *The ARRL Antenna Book*, ARRL Publication, Newington, Connecticut, 1984, pages 12-16, 12-17.
4. R.C. Johnson, and H. Jasik, *Antenna Engineering Handbook*, 2nd Edition, McGraw Hill Book Company, 1984, pages 17-17 through 17-22

(Continued from page 4.)

awards for his work, has authored numerous articles, and is associate chief of staff for research and development at Jerry L. Pettis Memorial Veterans Administration Medical Center, Loma Linda, California. He will discuss the basic science that supports our current knowledge of radiation hazards.

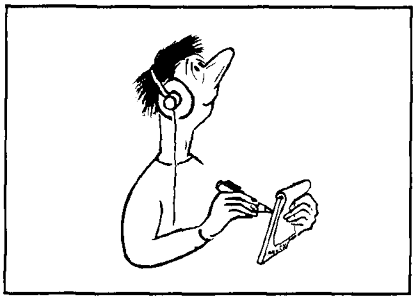
- Samuel Milham, Jr., M.D., Washington state epidemiologist. Dr. Milham, you'll remember, did the study that showed that hams, as well as electrical/electronic workers, suffered from higher than normal rates of certain leukemias and lymphomas (types of cancer).
- Ivan Shulman, M.D., WC2S, cancer surgeon. Shulman will discuss how the Amateur can take preventive steps to minimize the risk of exposure to the harmful effects of electromagnetic radiation.
- David Rodman, M.D., KN2M, ophthalmologist and writer for *Ham Radio* magazine. Rodman will cover his extensive work to quantify field strength measurments of both RF and 60-Hz field levels.

Again, it is important to stress that there is no "smoking gun" showing a clear, definable link between electromagnetic radiation and cancer or other diseases. There seldom is, at this early awareness stage of what may be a serious health problem. The latest reporting in the media, while prone to sensationalism and exaggeration, does emphasize the need to research this potential hazard further. In the words of one authority, "Something is going on here."

One must wonder why the ARRL's Bioeffects Committee has said almost nothing since its formation and Dr. Milham's first mention of his study of Calfornia and Washington state Amateur mortality rates in *Lancet*, April 6, 1985. (*Lancet* is a highly regarded British medical journal.) Hopefully, the ARRL will publish its policy and its findings soon. Silence, in this case, is not golden. It smacks of being afraid to "fess up" to a problem and admit that it might exist.

Is there a problem? It's likely that there is, but time, money, and thousands of hours of meticulous research are necessary to arrive at the final answers. *HR* is working on a number of different projects and will report its findings as they become known. Our intent is to inform — not fall prey to sensationalism, or blindly deny that a problem exists in the face of emerging evidence. We'll keep you, our readers, fully informed and up to date on all the latest developments.

Craig Clark, NX1G



Garth Stonehocker, KØRYW

EQUINOX SEASON DXING

The two equinox seasons are March-April and September-October. During these two periods of a few short weeks, the maximum usable frequencies (MUFs) make fairly rapid seasonal changes. For the spring equinox, the MUFs daily curve changes from a high peak near midday to a lower, broader one across the longer daylight hours of summer. The problems caused by these changes are magnified by a more direct alignment of the solar wind stream of charged particles into the polar region and from those stored in the earth's tail, which perturb the earth's magnetic field and, therefore, the ionosphere. As a result, the signals propagating between two points via the ionospheric mode can become weakened and variable in the mid- to high latitudes and near (±20 degrees) the geomagnetic equator.

The high latitude propagation is applicable to east-west paths like the US to EU or JA because the great circle of the path reaches as high as 67 degrees north latitude. The MUFs and the signal's amplitude variations usually decrease there. Both can be estimated from the geomagnetic A and K figures. In the equatorial region, the propagation is applicable to transequatorial path openings. Here the MUFs usually increase during the disturbance, but the signal is still weaker and variable. However, the variability is different because it's lower in amplitude changes and at a faster frequency — like flutter.

The disturbed period of last March-April is a good example of equinox season changes. The spring season is often more disturbed than the fall. This is probably because the solar flux is more often on a decreasing trend in the spring while it tends to increase in the fall, holding the earth's magnetosphere steadier from increasing solar radiation pressure. Therefore, solar flux and geomagnetic disturbance intensity tend to have opposite trends. Several large solar flares started off the month of March with some proton events and geomagetic disturbances indicated by the A figure of 20 to 30 units. Another on the 10th at 1922 UTC started a polar cap signal absorption, followed by a big geomagnetic disturbance of 248 A units — the largest recorded in the United States since 1960. Numerous reports of aurora, some as far south as Key West, Florida, showed the extent and intensity of this disturbance. Later in the month, another large flare on the 23rd at 1959 UTC caused a proton event in 41 minutes, and a sudden geomagnetic disturbance on the 27th at 1342 UTC. Large flares on the 24th and 26th kept the disturbance going until April 5th. A large flare at 0105 UTC on April 9th had little effect, until another occurred on the 23rd at 2155 UTC. This probably caused the geomagnetic disturbance of April 25th at 1859 UTC, which continued with minor flaring until May 7th. These are the major geophysical events of a typical high sunspot number equinox season. I'll report the propagation problems next month.

Last-minute forecast

The higher frequency bands are expected to be best, with longer openings the second and third weeks of September. The cause will be higher MUFs resulting from the expected high solar flux. These higher MUFs also cause a decrease in signal strength. A return of transequatorial one long hop openings in late evenings, especially during geomagnetic disturbances, can really enhance signal strengths. The disturbed periods may fall on the 6th and 7th, 13th through 15th, and 22nd and 23rd. Because this is the fall equinox season, there may be more periods of disturbance than those listed. The lower bands should improve with less thunderstorm noise and summer signal absorption both day and night. Expect better openings, especially from unique DX locations, in east-west directions during the disturbances. The full moon is on the 15th and perigee on the 16th. The autumnal equinox occurs on the 23rd at 0120 UTC.

Band-by-band summary

Ten, 12, 15, 17, and 20 meters provide many openings during the daytime. The openings will be shorter as you go up in frequency, centered around noon, and mainly in southerly directons. Fifteen meters is only a transition band between 12 and 17. Twenty meters, the mainstay daytime band for northerly directions, will be useful towards the south in the evenings.

Thirty, 40, 80, and 160 meters are all good for nighttime DX. Thirty and 40 meters are the night frequencies for the east-west and northerly directions, and for distances of 1600 miles.

WESTERN USA

GMT	PDT	N	NE	E	SE	S	SW	W	NW
0000	5:00	12	30	12	10	10	10	10	10
0100	6:00	12	30	15	10	10	10	10	10
0200	7:00	12	30	15	10	10	10	10	10
0300	8:00	15	30	15	10	10	10	10	12
0400	9:00	15	30	17	12	12	10	10	15
0500	10:00	20	20	15	12	15	10	10	17
0600	11:00	20	30	15	15	20	10	10	20
0700	12:00	30	30	15	15	20	10	10	20
0800	1:00	30	30	17	15	20	12	12	20
0900	2:00	30	30	17	17	20	12	12	20
1000	3:00	30	30	17	17	20	15	15	30
1100	4:00	30	20	17	17	20	15	15	30
1200	5:00	30	15	10	17	20	15	15	30
1300	6:00	20	15	10	12	20	17	17	30
1400	7:00	20	12	10	10	20	17	17	20
1500	8:00	20	10	10	10	17	17	15	30
1800	9:00	30	10	10	10	12	17	15	30
1700	10:00	30	12	10	10	12	15	17	30
1800	11:00	30	12	10	10	10	12	17	20
1900	12:00	30	15	10	10	10	10	12	15
2000	1:00	30	15	10	10	10	10	10	12
2100	2:00	30	17	10	10	10	10	10	12
2200	3:00	17	20	10	10	10	10	10	10
2300	4:00	15	20	12	10	10	10	10	10
		ASIA FAR EAST	EUROPE	S. AFRICA	S. AMERICA	ANTARCTICA	NEW ZEALAND	OCEANIA AUSTRALIA	JAPAN

MID USA

MDT	N	NE	E	SE	S	SW	W	NW	CDT
6:00	15	30	12	10	10	10	10	10	7:00
7:00	15	30	15	10	10	10	10	12	8:00
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PRODUCT REVIEW/NEW PRODUCT

OCTOBER 1989 / $2.95

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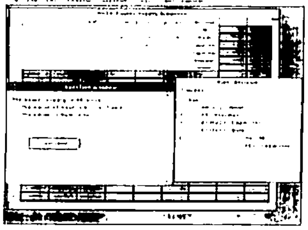
An Exclusive First Look at Kenwood's TS-950S

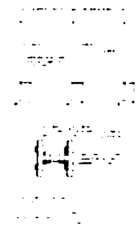
Computerizing Smith Chart Network Analysis

Variable Gain 160-Meter Preamp

HAM RADIO



WB5IRI, page 22



NU1N, page 30

OCTOBER 1989
Volume 22, Number 10

Cover photo: *Ham Radio* takes an exclusive first look at Kenwood's TS-950S transceiver. See page 28 for features and preliminary specifications. Photo courtesy of Kenwood USA Corporation.

FEATURES

DEPARTMENTS

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Photo courtesy of the *Keene Sentinel*

Henry Gallup
1940 – 1989

Farewell to a Friend

One of the hardest things one has to do as a writer is to compose the obituary of a friend. I remember my first year in journalism school. The "obit" was simply another piece of specialty writing you had to learn. There was a formula to it. A way to handle the family. A way to get facts from funeral directors — something beyond the standard phrase "he died after a long/short illness." As I sit here tonight, I find the formulas mean nothing to me any longer. *My* friend has died and the what, when, where, why, and how doesn't matter — just the who.

Late in the afternoon on August 22nd, I received word that Henry Gallup, N1GCF, *Ham Radio*'s Director of Advertising Sales, had died suddenly, and most unexpectedly. He was only 48. He leaves behind his family — all of whom he loved very much. He was a responsible man who took his work seriously.

Henry's death was a great shock to all of us here at *Ham Radio*. He was a part of our lives for a short year and a half, but he gave us a great deal. Henry always had a ready smile, or a joke. I found he was always there when I needed to talk. He was a man of great caring and compassion. I truly believe that he accepted each person just the way he was, unconditionally, without judgment. If I was having a problem, I could always count on Henry to give me some perspective.

Many of you only knew Henry as a voice on the phone, looking for this month's ad or trying to sell you a little more space. Others met him at Amateur Radio shows. You may not have gotten to know the Henry I knew, but I'm sure you warmed to his wit and his charm.

How do you say goodbye to a friend? You reminisce, remember the last time you saw him, the funny things he used to say, the things he did that drove you crazy. You replay them over and over in your mind until they're worn and threadbare. And then, you finally say goodbye.

Goodbye Henry. I'll miss you. All of us will.

Terry Northup, KA1STC

Amateur Radio Licensing Fees — the "Non-Tax" Tax

On July 13th the House Energy and Commerce Committee voted to levy fees on Amateur Radio licenses and several commercial ventures. They did this to reduce the Federal budget deficit by means of a "tax that isn't called a tax." That, frankly, is a bunch of baloney. The deficit is in the billions; this proposal will raise an estimated 50 million dollars at most. I originally wrote this editorial several months ago and find it rather remarkable that the House "picked up" on my thoughts. But don't blame me for their action. My idea has merit and, if not limited by statute, would be worth further consideration.

We live in an era of government deregulation. Over the last ten years, the government's grip on regulation has slowly loosened in almost all areas of our lives, from airline travel to telecommunications services. AT&T no longer has a monopoly on long distance telephone service. New technology, spurred by deregulation, is coming online daily.

In the Amateur service, we no longer need to keep daily logs. Nor do we have to send a letter to the FCC Engineer-in-Charge when we operate portable. The FCC is no longer directly involved in the testing of new Amateurs. Who would have thought any of this possible twenty years ago?

However, deregulation does have a downside. Great concern has been voiced in the Amateur ranks about rules enforcement. Hams everywhere wonder what can be done to improve this situation. The FCC has neither the staff nor money to enforce rules the way they used to. The FCC budget, the whole thing, is about the same as one Pentagon weapons system procurement budget. An ex-FCC staff member stated that the Commission is using "mirrors and illusion" to keep programs running. Staff reductions due to budget cuts don't allow a lot of extra fat.

Another source of funding is needed if the FCC is ever to return to monitoring the airwaves and enforcing Amateur rules and regulations. I'm talking about the principle of "TANSTAAFL;" there ain't no such thing as a free lunch. Perhaps the time has come to institute a system of user fees to support the FCC's licensing and enforcement activities. This was proposed in the past and was met with a storm of protest. But if we could institute a system where all fees were put into the FCC's budget, as opposed to the General Fund, perhaps we could have many of the activities we'd like. It would take judicious planning. Funding for monitoring and enforcement could be expanded to allow the FCC to act on bad operating habits and illegal activities.

I would be more than willing to pay for the privilege of my Extra class license. What is it worth to me? At least $20 per year — maybe more. Would I write a check for $200 for my 10-year renewal? Yes, if I knew that the money was going to go to the FCC and not into the Federal Government's General Fund. I would propose a sliding scale of rates based upon the license class. Extras would pay the largest fee; beginners would pay a relatively nominal amount, perhaps nothing at all.

Unfortunately, there's more than one problem with this proposal. In the sixties, the imposition of FCC fees was one of the biggest reasons for the lack of growth (and even a decline) in Amateur numbers. When you look at the FCC numbers from that era, you can see the dramatic result of fees on licensing. Hams and potential hams simply didn't want to pay a fee to get their Amateur ticket. Based upon past experience, one would expect history to repeat itself. Reimposition of user fees could have a serious affect on the growth of the Amateur service. Secondly, by statute, user fees are put into the government's General Fund instead of going to support the collecting agency. In other words, the user fees become nothing more than an additional tax, though the "politicos" don't have to label it as such.

So, we are caught in a dilemma. There's little chance of an increase in the FCC budget. Yet the last time user fees were implemented, there was a downturn in Amateur licensing numbers. Amateurs want more from the FCC. What's to be done?

I wish I had the answer. This question is full of traps and pitfalls. While the Energy and Commerce Committee's idea has merit, Amateur Radio will derive little or no benefit if the monies simply go into the General Fund. Should the Committee's recommendations go any further, I strongly suggest that you write to your local representatives and express your feelings on the matter. For myself, if Congress could arrange for the fees collected to go to the FCC — fine; I'm in favor of the proposal. However, if the fees go into the General Fund — sorry, no. My taxes are high enough as it is now. Don't try to flim-flam us with a "non-tax" tax. Hams are not stupid, and we don't forget when it comes time for re-election.

Craig Clark, NX1G

Comments

Packet radio made simple

Dear HR

Congrats to Tom McMullen, W1SL, on his article, "Packet Radio for the First-timer." Clearly, Tom has found a way to present his material in an understandable manner to neophyte packet ops like me. After reading his article several times, I feel confident to attempt my first QSO via packet radio. Frankly, after reading the operations manual provided with my TNC, I became more confused as to what to do first. My question is: why can't TNC manufacturers write their manual in a simple form similar to the style that Tom's article is written? I feel that my manual is completely unsuitable for someone just getting started in packet radio. Tom's work was indeed a sight for sore eyes, and I would like to see additional articles on packet written in the same manner.

Walt Bilous, WA2DQB,
Linden, New Jersey

Code/No Code Choice

Dear HR

Must we always see things as either black or white?

For those who believe in the no-code license, simply taking out the code part would make the tests too easy. In short, it would be the equivalent of opening the ham bands to the same general public who ruined CB with illegal practices and lack of consideration for others. Also, there *are* pre-teen hams on the air — surely those having a genuine interest in becoming a ham have a better excuse than "the code is the primary obstacle to obtaining my license."

Many of those in favor of the pro-code exams have the "I had to take it so you should too" mentality. This isn't a legitimate reason for maintaining the pro-code test but a childish one.

I propose a compromise to the code/no-code debate. Applicants should be given a choice of taking either the standard code-and-theory test, or a substantially harder theory but no-code test. An applicant who opts for the more difficult theory but no-code test may not be able (or want) to communicate in Morse, but at least she/he might have a technical edge over the ham who opts for the current theory-and-code test, and doesn't really know how to design or construct a working antenna/radio system.

With either choice of test, the key ingredient in obtaining the license is still dedication. If we are to maintain the feeling of pride and responsiblity in having and using a ham radio license, we have to keep it a challenge to earn one.

Richard Stuart, WF7A,
Lynwood, Washington

Many benefits along the way to a career

Dear HR

To me, Amateur Radio is an intriguing hobby that led to a professional career as a consultant in electromagnetic interference and RF circuit design. Licensed as WN6RHM in 1952, I remember discovering by the direct experience method that the 6L6 oscillator/transmitter described in "How to Become Radio Amateur" (ARRL publication of that era) radiated equally well on all bands 80-10 at the same time. I remember to this day the excitement of working WN6UJX in Van Nuys, California as my first contact.

I am still in frequent contact with Wil Claus, K6DKA, whom I met in junior high school in the seventh grade. So amongst other things, Amateur Radio holds forth as a source of lifelong friends that I doubt could be obtained by other means.

Some of the technical insights gained by the hands-on experience of trial and error of those younger days give emphasis to the theories of electromagnetic and electronic effects learned since. In that regard, I think it must be said that Amateur Radio is a resource in addition to a service and/or a hobby. For it is from that resource that many of tomorrow's engineers and scientists will come. The importance of exposing today's youth to this hobby *cannot* be overemphasized. For some, as it did for me, it may grow into an avocation yielding life long friends as a by-product along the way.

As to the issue of how much spectrum is enough for the hams, I doubt that any of us will resolve that issue. I will say however that as both a professional and an "Amateur" in the field of communications, there is little doubt that Amateur Radio could use some sprucing up in the image department when it comes to the nature of the use of the spectrum. For example, some VHF repeaters here in Southern California are simply an embarrassment to the sport of radio communication, and its public image.

However, the future of Amateur Radio lies with the youthful licensees of today. Some of them will no doubt gain from this hobby and therefore be in a position later to return something not only to the hobby, but to society as a whole. Let us hope that the practices of the detractors and abusers of the privileges associated with Amateur Radio do not result in the complete loss of spectrum space.

Steve Jensen, W6RHM,
Running Springs, California

COMPUTERIZING SMITH CHART NETWORK ANALYSIS

Network calculations made easy

By Richard A. Gardner, N1AYW, 49 Notre Dame Road, Bedford, Massachusetts 01730

The Smith Chart is a versatile, time-saving tool useful for solving many Amateur Radio circuit and network design problems. It addresses network equations graphically, eliminating the need to wade through the math. Even so, using the paper Smith Chart can be a time-consuming process — especially if many network element changes are involved. Having used paper Smith Charts, I knew how useful they were but I wanted a more efficient approach. I have developed a BASIC computer program for the Smith Chart that is easier, faster and more accurate than the paper chart.

I first used the Smith Chart when trying to understand the effect of a matching network on a triband beam. The antenna and matching network had an SWR much higher than acceptable, so I needed to isolate the problem to either the antenna or matching network. Because I made the antenna system impedance measurement from my shack, I used the Smith Chart to separate the effect of the 100-foot coax feedline from the antenna system measurement.

The second time I needed to use Smith Chart calculations was when I decided to use my antenna tuner as a measurement instrument. Because the Smith Chart can handle not only transmission line problems but also circuit networks made up of lumped components, capacitors, inductors, and resistors, I reasoned that I should be able to use the chart to work backwards from 50 ohms to find the conjugate antenna impedance. All I needed to do was calibrate and model the antenna tuner capacitors and variable inductor accurately. However, when I was working on the right side of the Smith Chart, small positional changes represented significant changes in component values, and it was extremely difficult to come up with an accurate measurement. What I needed was a computer-aided chart to provide computational accuracy.

These two tasks gave me some incentive to explore a computerized Smith Chart. The basic ideas for this program came from two excellent articles by Lynn Gerig.[1,2] I've corrected some errors, added features (like modular computation structure), included additional network elements, incorporated hyperbolic functions into transmission line equations to account for line losses, provided for recall of prestored user-defined loads, and rewritten the program for use on IBM PCs and compatibles. I found that these additional features made the original program even more useful.

Since improving the computerized Smith Chart, I have found many uses for it — including the design of matching networks for amplifiers, antennas, and oscillators, and determining transmission line effects on antennas and filters. The computerized version is faster and provides a more precise output than is possible with the paper chart. The program structure and equations have been developed to address the specific capabilities I needed in a computerized Smith Chart. I've made many changes to the program as my needs have changed. I expect other users may also want to make changes; the modular structure makes customization straightforward.

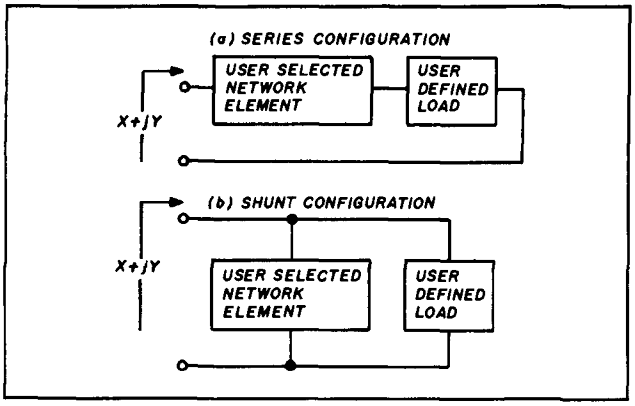
What does the program do?

The Smith Chart Network Analysis program calculates the resultant impedance of user-selected network elements in series or shunt, with a user-defined load. The two network configurations are shown in **Figure 1A** and **1B**. The resultant impedance is then plotted on a Smith Chart, which is reproduced on the screen. The user-selected network elements can be either lumped components or transmission line sections.

A subprogram, which calculates component values for series and parallel resonant circuits, is included with the Smith Chart Network Analysis program. It can also be used alone. I've found it's very helpful when used in conjunction with the Smith Chart, while solving resonant network problems.

As shown in **Figure 2**, complex numbers are used to describe the various impedances with R + jI representing the user-defined load, A + jB representing the user-selected network elements, and X + jY denoting the resultant impedance. The user-defined load must be described as a series resistance and reactance at each frequency of interest. If you have a load in mind which is described as

FIGURE 1



User Selected Network Element and User Defined Load connections for series and shunt configurations.

FIGURE 2

User-defined load	**R+jI**
User-selected network element	**A+jB**
Resultant impedance	**X+jY**

Resultant impedance for series combination

$$X+jY = (A+R) + j(B+I)$$

Resultant impedance for shunt combination

$$X+jY = \frac{A(I^2 + R^2) + R(A^2 + B^2)}{(A + R)^2 + (B + R)^2} + \frac{B(I^2 + R^2) + I(A^2 + B^2)}{(A * R)^2 + (B + I)^2}$$

Complex notation for User Selected Network Elements, User Defined Loads, and resultant impedances. The equations are for the series and shunt configurations.

a parallel combination of elements, you can find the series equivalent using the Smith Chart program. **Appendix A** describes how to do this. The essential calculations performed by the program are those which compute numerical values for the user-selected network element and for the resultant impedance. The resultant impedance is displayed in complex notation and also plotted on the Smith Chart as shown in **Figure 7**.

Figure 3 illustrates the 24 network elements contained in the program. Some of them are redundant, but are included for convenience. For example, the series RLC element could be formed by selecting (in turn) a series R, a series L, and a series C; however, it's rather slow and cumbersome. You can generate your own network elements by expressing the network element's impedance in complex form and using it to replace an existing network element in the program.

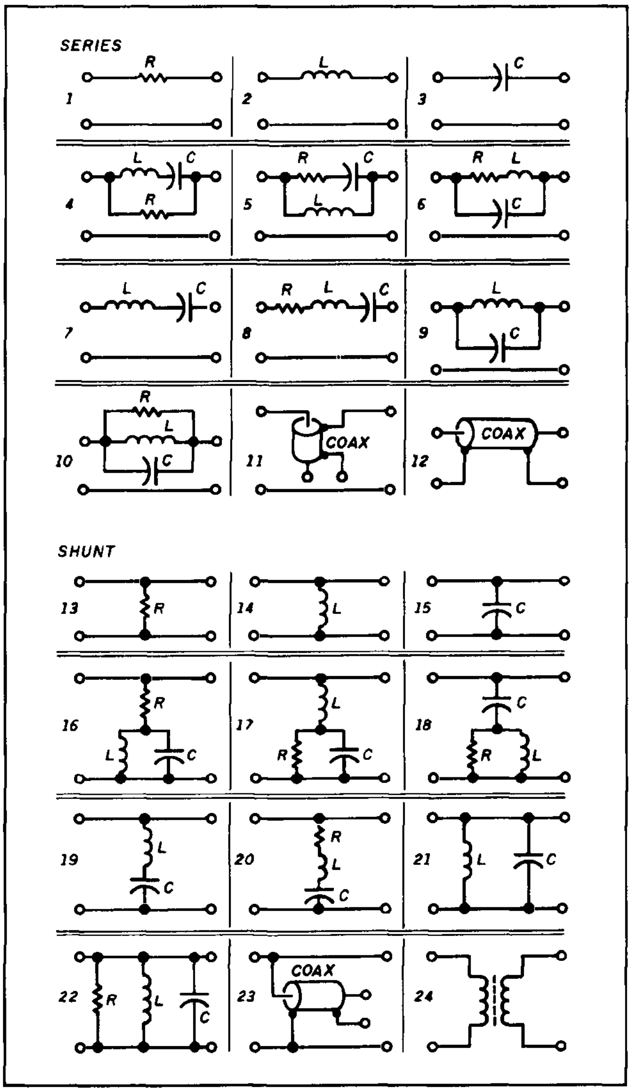
You can select five transmission line configurations: a transmission line in series with the load, an open or shorted stub in parallel with the load, or an open or shorted stub in series with the load. Transmission line computations take line attenuation into account. The attenuation for six common coax cable types is calculated automatically at the frequencies of interest. The attenuation equations are based upon attenuation curves in **Reference 3**. The program will also accept a single user-supplied attenuation value if one of the six cable options isn't selected.

You can select a step-up or step-down transformer for insertion in series with the load. The transformer is assumed to be ideal; however, transformer leakage and magnetizing inductances and stray capacitances can be simulated by using the appropriate network elements, along with the transformer element.

Sample problem

Here's a simple design to clarify what I've described so far. (Those not familiar with the Smith Chart may want to read **Appendix B** for some help in using a Smith Chart before proceeding.) Say you want to use a 40-meter antenna on 30 meters. To obtain an acceptable SWR, you'll need some kind of matching network. You'll need the

FIGURE 3

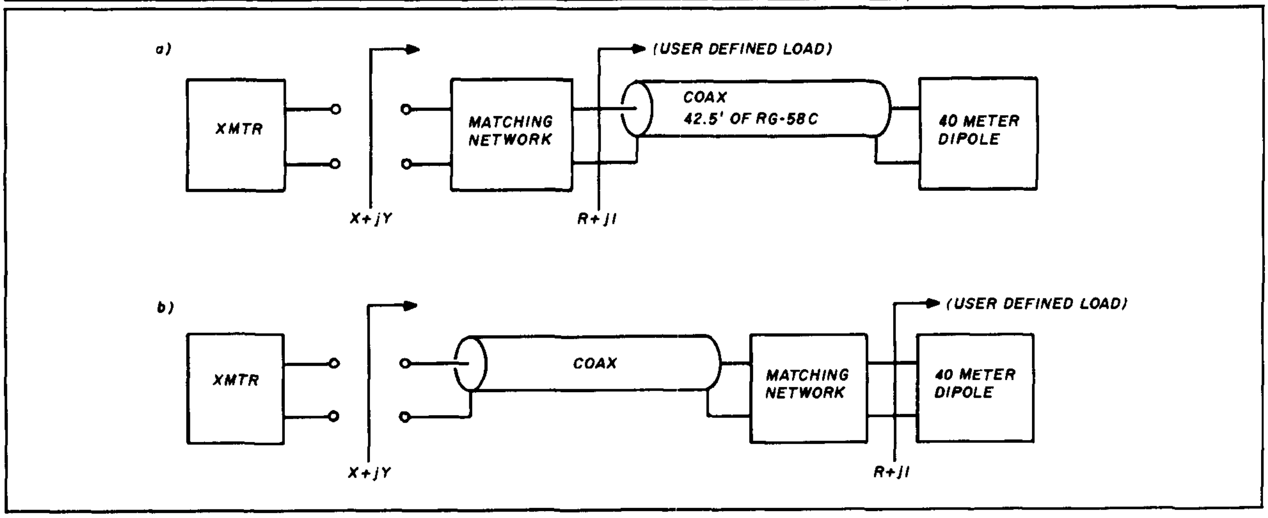


Network Elements that can be selected to form matching network designs.

impedance of the 40-meter antenna system measured at 30 meters to begin the design. Using a noise bridge, measure the combined dipole and feedline impedance at 30 meters. **Table 1** shows the measured load values, R + jI, of my 40-meter dipole at the frequencies of interest, and this data will be entered into the program when requested. The user-defined load in this case is the 40-meter dipole/feedline shown in **Figure 4A**. If this load were driven without a matching network, it would present the SWRs shown in **Table 1** — values that are calculated by the program.

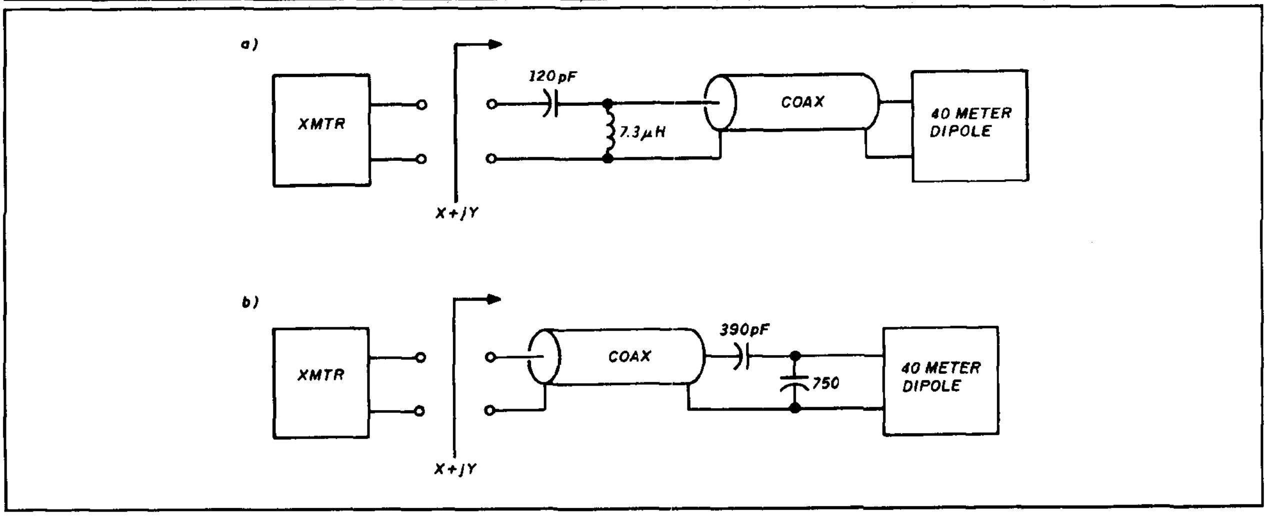
There are two possible places to insert a matching network: one is down in the shack (see **Figure 4A**), and the other is up at the antenna (see **Figure 4B**). The first design example, shown in **Figure 4A**, will describe a matching network connected at the transmitter end of the coax. This matching network will be made up of a combination of shunt and series network elements. Although there are literally an infinite number of matching network configurations that could theoretically satisfy the requirements, I chose a simple L-network for this demonstration. (Once you're familiar with the Smith Chart, the network configurations that can perform the match become readily apparent.) This simple L-network consists of a shunt L and series C, as shown in **Figure 5**. Note that the order in which the network elements are used is important. The shunt inductor must be adjacent to the load followed by the series capacitor. Placing the components in the opposite order will generally result in a different impedance.

FIGURE 4



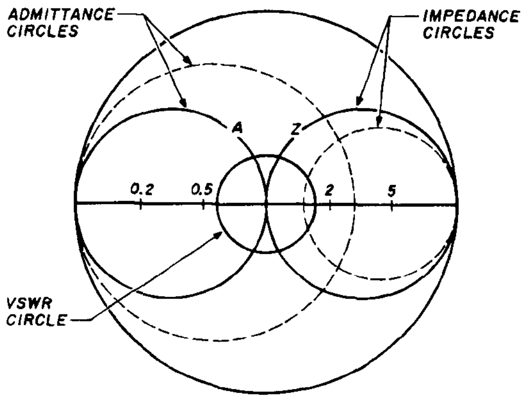
Diagrams showing the matching network and user defined load configuration for the sample problem described in the text. *Figure 4A* shows a matching network located at the transmitter end of the coax. *Figure 4B* shows a matching network located at the antenna end of the coax.

FIGURE 5



Sample problem matching network solution and component values.

FIGURE 6



Smith Chart showing two admittance and two impedance circles. The solid admittance and impedance circles pass through the chart's center, 50 ohms.

In this example, the matching network consists of two user-selectable network elements — a shunt inductor and a series capacitance. Values for these components will be determined later, but first be sure you understand that the *user-defined load* is the 40-meter dipole and feedline characterized at 30 meters. In this case the matching network consists of two user-selected network elements, a shunt inductor, and a series capacitor.

The design objective is to obtain an acceptable match at the frequencies listed in **Table 1**. Do this by looking at the plotted load points on the Smith Chart, and by trial and error. Select a shunt inductor value which drives the resultant impedance (X + jY) to the circle labeled Z in **Figure 6**. If you try an inductor value of 7.3 μH, the new resultant impedance points will be located roughly on the Z circle perimeter. Note that the real part of the impedance is now very close to 50 ohms. Now, select a value of series capacitor which will move these points down toward the center of the chart — the 50-ohm point. Trial and error shows that 120 pF is an acceptable capacitor value (see **Figure 5A**).

The second design approach assumes that the matching network will be placed at the antenna, as shown in **Figure 4B**. Again, start with the measured data in **Table 1**. In this case the 40-meter dipole is the desired user-defined load, but in order to determine its impedance the feedline effect must first be removed from the impedance measurement made in the shack. If you were using a paper Smith Chart, you could calculate the feedline length in fractions of a wavelength and then rotate the impedance points in the correct direction to determine the dipole's impedance. Removing the feedline's effect is much simpler with the Smith Chart program. Simply choose a negative value for the feedline length when the program requests the line's length. Cable length is entered in inches, and since the cable length is 42.5 feet, enter −510 inches as the feedline length. **Table 2** shows the dipole's calculated impedance or user-defined load for this example. As in the previous example, there are many possible matching network configurations that will satisfy the requirement. For this example, select a simple matching network that consists of a shunt capacitor followed by a series capacitor. Using the Smith Chart Network Analysis program and selecting values of 750 pF and 390 pF, respectively, will result in an impedance close to 50 ohms. The actual impedance values are shown in **Table 3**. These impedance values represent the combination antenna and matching network impedance. This load impedance will be connected to the transmitter through the feedline coax. To find the load seen by the transmitter, select the series transmission line network element. Since 42.5 feet of RG-58A coax is being added back into the system, select +510 inches when prompted for coax length. The computer will then calculate the transmitter load shown in **Table 4**.

From the SWRs shown in **Tables 3** and **4**, you can see that the matching network design has been successful.

TABLE 1

40-meter dipole plus feedline impedance on 30-meter band.

Frequency	R	jI	SWR
10.100	95.0	+j161	7.75
10.125	95.6	+j171	8.43
10.150	96.9	+j181	9.11

TABLE 2

40-meter dipole impedance on 30-meter band.

Frequency	R	jI	SWR
10.1	4.1	+j17.1	13.8
10.125	3.4	+j17.1	16.4
10.15	2.8	+j17	19.7

TABLE 3

40-meter dipole with matching network.

Frequency	R	jI	SWR
10.1	56.8	−j7.1	1.2
10.125	55.7	+j2.8	1.13
10.15	53	+j12.0	1.29

TABLE 4

Impedance seen by transmitter.

Frequency	R	jI	SWR
10.1	47.3	−j0.2	1.06
10.125	54.6	−j2.8	1.11
10.15	62.8	−j6.6	1.29

Program description

The program is menu driven and contains enough direction to be used with minimal help, provided you have a basic understanding of Smith Charts. For those readers who are unfamiliar with them, I recommend **References 4** and **5**. I've included a very brief description of Smith Chart operation in **Appendix B** to get you started.

The program is designed to use default values if you offer no input. Default values are either the initialization values, entered automatically at program start, or the last value you enter. When the program prompts for a new value, the default value is displayed followed by a ?. If you wish to use the default value, simply hit the Enter key.

When you're asked a question requiring a simple yes or no answer, hit the Y or N key as appropriate to carry out your action. When entering "letter" answers, you can use either upper or lower case.

The program starts out with a four-item menu.

* CHOOSE AN OPERATION *
START A NEW NETWORK = 25
RESONANT CALCULATIONS = 26
CLEAN UP CHART = 27
REVIEW NETWORK = 28

The default selection is 25, "Start a New Network." This is the way you'd normally start a design. An alternative starting point is the "Resonant Calculations" selection. This selects a subprogram which permits the calculation of series or parallel resonant circuit parameters like Q; resonant frequency; or R, L, and C values. When you've completed resonant circuit calculations, you'll exit back to the main Smith Chart program. Don't select operations 27 and 28 initially; they are useful only after a network design has started.

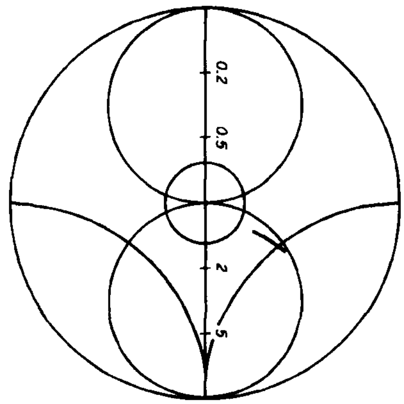
Once you've selected the Start a New Network operation, the program enters the setup mode. During setup, program constants are assigned, variables are initialized, and user-selectable parameters are established. The first setup parameter requested is the SWR circle radius. A circle will be drawn on the Smith Chart and all plotted points that fall within this circle will have a SWR less than the value you specify. A default value of 1.5 is used if you don't offer a value. The program goes on to request the Smith Chart impedance. This impedance defines the chart's center impedance. For example, if you wish to match a load to a 72-ohm system, you would select 72 ohms as the chart impedance. Because I work most often with 50-ohm systems, the default value is set at 50 ohms.

Next, you'll be asked if you want to recall prestored load data. (The prestored load data currently listed describe my antennas, and are probably not of use to most of you.) You may want to enter the impedance of your antennas or other selected loads into the data statements. It's particularly useful for those user-selected loads that are used repeatedly. Prestored load data begins at program line 4430. **Appendix C** discusses how to modify the prestored load data.

If you don't select the prestored load data, the program will ask: "How many frequencies?" (For how many frequencies do you wish to calculate the resultant impedance?) Initially, you might select two or three frequencies across the ham band of interest, until you get an idea of how the program works. You can enter up to ten frequencies.

The program now requests the frequency in MHz and the load impedance at each frequency. It will continue to request this information until you've entered all frequencies and load impedances. When all data have been entered, the program will give you an opportunity to check the data and make changes. It will ask: "Are you satisfied?" Simply enter Y if the displayed data are correct, or N if not. If you answer no, the computer gives you another opportunity to load prestored data. If you answer no to that choice, you'll be given a chance to repeat the data entry process, correcting the errors as you go. Because previously entered data will now be the default data you need, enter only the corrections. When all data are correctly entered, you'll be given the option of printing the user-defined load data. *Do not elect to print unless a printer is connected, or the computer will hang up.* If that happens, you'll have to reboot the system and you'll lose all the network values you've entered.

FIGURE 7



Frequency	RS	XS	SWR
10.1	56.8	33.3	1.87
10.125	55.7	43.1	2.23
10.15	53.0	52.2	2.66

Select any key to continue

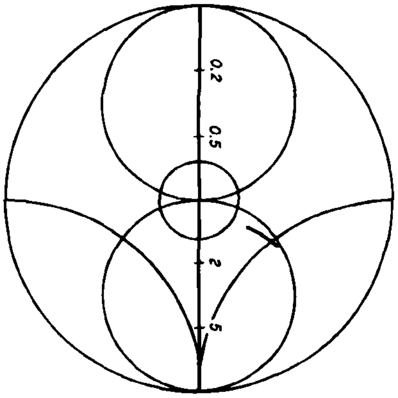
Impedance and Smith Chart as displayed by the program. The resultant impedance, X+jY, is displayed and plotted on the Smith Chart as shown. Note that the notation X+jY is used in the BASIC program, but the resultant impedance is displayed as Rs and Xs on the screen. Rs = X, the series resistance, and Y = Xs, the series reactance.

The program now plots your load data on the screen along with a simplified Smith Chart, as shown in **Figure 7**. Note that the frequencies are plotted in the order in which they were entered. The first frequency is plotted with a small circle, the second with a medium circle, and the third with a large circle. The sequence begins again with the fourth frequency. This display permits an unambiguous identification of each frequency — a feature which will be helpful as your design proceeds.

As shown in **Figure 8**, a menu which lets you select either series or shunt networks elements is displayed beside the Smith Chart. After you enter an element number, the computer prompts for component values. After they've been entered, the new resultant impedance is displayed on the Smith Chart, along with the real and imaginary numerical values. At this point the program asks: "Do you want to accept this run?" Select N if the resultant values aren't acceptable, and you'll be given an opportunity to select new component values. If the values were acceptable, the program will display your design configuration to this point.

For users with a poor short term memory (like me), there's a recall feature that permits review of the elements

FIGURE 8



Choose a network element

Element	Series or	Shunt
R =	1	13
L =	2	14
C =	3	15
R/LC =	4	16
L/RC =	5	17
C/RL =	6	18
Series LC =	7	19
Series RLC =	8	20
Parallel LC =	9	21
Parallel RLC =	10	22
Stub line =	11	23
Trans. line =	12	-
Transformer =	-	24

Choose an operation

Start a new network	=	25
Resonant calculations	=	26
Clean up chart	=	27
Review network	=	28
Enter # 1 to 28		M = 27?

Smith Chart Network Analysis program menu display.

"accepted" during the current design session. This is helpful in recalling the order and the component values selected for the final design solution. You can obtain a hard copy by using the "PrtSc" key.

After you have selected elements within a design, the Smith Chart becomes a bit messy. I've included a feature to clean up the chart, which clears out all intermediate impedance plots, and replots the Smith Chart with only the latest design values.

Getting started

Try the sample problem while following the procedure outlined in **Appendix** B. Experimenting with each of the network elements in **Figure 3** will help you understand how series and shunt components transform impedances. I'm sure you'll find designing with the Smith Chart an enjoyable and efficient process.

If you'd like to type in the program, you can obtain a copy from *Ham Radio* by sending a business sized SASE. For those who don't like to type, I'll provide a copy of the program on disk to anyone who sends me their mailing address and $5 to cover postage and mailing materials.

I've written the program in BASICA and configured it to operate on an IBM XT or AT equipped with an EGAWondercard. Although I haven't tried, I believe it will also run with an IBM EGA card. The program has been run using HBASIC (used with the Hercules graphics card), Microsoft QuickBASIC, and GWBASIC. When you run with the EGAWondercard, you should select the option 2 or 3 display mode before entering the BASIC interpreter or compiler. I have also run it on an AT and XT equipped with the Hercules graphic card and on the Toshiba TS1100 and Zenith ZWL-183-92 lap top computers.

Appendix A

Converting a parallel network to a series equivalent

Assume you have a load that is a parallel RLC network and you want to generate the series equivalent, R + jI, at frequency f1. First select one component of the RLC network to be the user-defined load; it doesn't matter which one. Then use the program to add the other two components in parallel with the first one selected. The program calculates the resultant combination, and displays the result in the series form, R + jI.

For example: take a RLC network whose individual values are known to be R = 300 ohms, L = 4 μH and C = 240 pF. Select the 300-ohm resistor as the user-defined load and, when the program requests it, enter the load parameters R = 300 ohms and I = 0 at the frequency of interest. (You can choose more than one frequency if you wish. Just enter the other frequencies when requested, but enter the same load, R = 300 and I = 0.) Next, choose a parallel LC from the network elements, number 21, to be put in shunt with the 300-ohm load. The LC values for this example will be 4 μH and 240 pF, respectively. The result calculated by the program for f1 = 7.2 MHz is 84.3 − j134.9. This is equivalent to a resistor of 84.3 ohms in series with a capacitor of 163.9 pf. Remember that this equivalence is valid only at 7.2 MHz.

Appendix B

How to use a Smith Chart for impedance matching

I strongly recommend that those who enjoy RF circuit

design learn how to use the Smith Chart. A description of some basic procedures necessary to design a simple matching network follows. To gain a thorough understanding, check out references 4, 5, 6, and 7.

Although network problems could be solved with a set of simultaneous equations, the Smith Chart does the calculation for you while providing a graphic insight into the problem. It also provides potential solutions that the equations don't supply, and does away with many tedious calculations.

There are three circles within the Smith Chart circle (see **Figure 6**). The circle tangent to the left side of the Smith Chart is an admittance circle; the one tangent to the right side is an impedance circle. There are other admittance and impedance circles that can be drawn; however, these two are especially important because they pass through the chart's center. You can choose any value you wish for the chart's center impedance; for this discussion assume it is 50 ohms. The middle circle is the SWR circle and will be discussed later.

Other larger and smaller diameter admittance and impedance circles can be drawn, but they must be tangent to the left or right of the Smith Chart, respectively. (These other circles aren't shown in the computer display because I wanted to keep the chart relatively simple.) Reactive components (capacitors or inductors), placed in series or parallel with a load, will cause the load impedance to shift along these circles or paths. Shunt components cause shifts along the admittance circles and series components cause shifts along impedance circles. Capacitors cause shifts toward the bottom of the chart and inductors cause shifts toward the top. With these basic rules, you can design a simple matching network.

Enter the abritrary load impedance, the frequencies of interest, and the desired SWR into the program. The program will draw a Smith chart on the screen, along with the points which represent your arbitrarily selected load. The "matching network game" objective is to select network elements which will move the load toward the 50-ohm point — the center of the Smith chart. However, the rules constrain you to move only along impedance or admittance circles to reach the center. Any impedance or admittance circle can be used as part of the path to reach any other circle on the way to the center.

Because the match does't have to be exactly 50 ohms to work properly, a màtching performance criteria or SWR is used. A SWR of 1.5 or less is selected for this example, and when all load impedance points fall within this circle, the desired match will have been achieved.

Using **Table 1** data which are plotted in **Figure 6**, you can see that the user-defined load falls inside the impedance circle labeled Z. There are several design solutions available, but two very straightforward approaches involve moving the load impedance to the Z circle. Do this by moving the load impedance either up or down along an "invisible" admittance circle. Moving up along an admittance circle implies using a shunt inductor; moving down implies using a shunt capacitor as the first element in the matching network. Once you've moved the load impedance to the Z circle, you must move it to the center of the chart. If you first used a shunt capacitor to move the load to the Z circle, you have to select a series component to move it along the Z circle. Because the impedance must be moved upward, a series inductor is required. If you used a shunt inductor to get the Z circle, you'll need to use a series capacitor to move down the impedance circle toward the Smith Chart's center.

I've been shown that two component combinations can move the initial impedance toward the 50-ohm point. Choose a combination for this design and determine the component values by selecting trial values and letting the program calculate and display the new resultant impedance.

Use the Smith Chart Network Analysis program to determine the component values which move the load the proper amount. Try a few values to see how the load impedance is moved on the chart. After entering the load values from **Table 1**, select a shunt capacitor from the menu for the first component. When prompted for a value, make a guess based on your experience, or from the capacitor values available in your junkbox. You'll find that if you try a value of 100 pF, the load doesn't move downward far enough, but appears to move about half the distance. A value of 170 pF will cause the three load points to straddle the Z circle line. For the series inductor, a little experimenting will lead to a value of 2.2 μH. All three points now fall within the SWR circle of 1.5, with the displayed numerical values showing a maximum SWR of 1.21.

Appendix C

Changing prestored load data

Prestored load data are contained in data statements at the end of the program starting at line 4430. The data must be entered in a specific format in order to be interpreted correctly by the Smith Chart Network Analysis program. Data are entered with frequency in MHz first, the real part (R) of the load impedance second, followed by the load impedance's imaginary part (jI). For example, if the load had an impedance of 27 + j34 at 14.2 MHz, and 29 + j38 at 14.3 MHz, the data statement would be:

DATA 14.2,27,34,14.3,29,38

REFERENCES

1. L. Gerig, "Computer Interface for Smith Chart Calculations," *RF Design* January/February, 1982.
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3. *The ARRL Handbook for the Radio Amateur*, ARRL, 1985.
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5. "HF Transistor Amplifier Design," *RF Design*, September/October, 1981.
6. P. Smith, "Transmission Line Calculator," *Electronics*, January 1939.
7. P. Smith, "An Improved Transmission Line Calculator," *Electronics*, January 1944.

THREE-ELEMENT VERTICAL DRIVEN ARRAY FOR 10 METERS

By Douglas Rowlett, Ph.D., WB5IRI, 2603 North Brompton, Pearland, Texas 77584

Ten meters is wide open to Europe and Africa in the mornings, and to Japan and Australia in the evenings. But you just can't seem to break through the pileups — all the guys with their kilowatts and six-element monobanders at 70 feet grab the DX before you can even hit the microphone switch. Your barefoot transceiver and trap dipole just don't cut the mustard. Sure, you make a few contacts overseas — but your signal reports are always low, and no one wants to ragchew the way they do with those who are putting in better signals. Even if you had the money, your neighborhood's deed restrictions make a tower and rotatable beam out of the question, and an amplifier would only cause more TVI.

Sounds familiar? Well, why not try a vertical driven array? A three-element array for 10 meters is only 8 feet tall by 17 feet long, and should fit in the smallest backyard. The antenna in **Figure 1** is an end-fire array with elements 2 and 3 fed 90 and 180 degrees out of phase, respectively, relative to element 1. The array provides about 4.5-dB gain over a single quarter-wavelength vertical, has a front-to-back ratio of 15 to 20 dB, costs less than $30 to build (even if you buy everything new), and can be erected in a single weekend. Separate gamma matching for each element simplifies adjustment and provides a low VSWR. Its low height makes this array unobtrusive, and if you mount the elements in your backyard the neighbors won't even know it exists. The major lobe is fairly broad, and the beam heading can be switched 180 degrees by swapping the phasing lines to elements 1 and 3.

Construction

The elements are made of 3/4-inch diameter EMT conduit, which sells in hardware stores for under $3 a 10-foot section. The gamma-matching rods are made from 1/2-inch diameter EMT conduit, which runs about $2 per 10-foot section. The shorting bar, clamps, and coax-connector support are made from the U-shaped two-hole straps commonly sold as wall fasteners for 3/4-inch conduit (see **Figure 2**). These usually sell for about $1.25 per dozen. Radials for each element are quarter-wavelength sections of whatever size wire you happen to have on hand. It doesn't matter whether the radial wires are solid or stranded, and insulation on the radials makes no difference in performance.

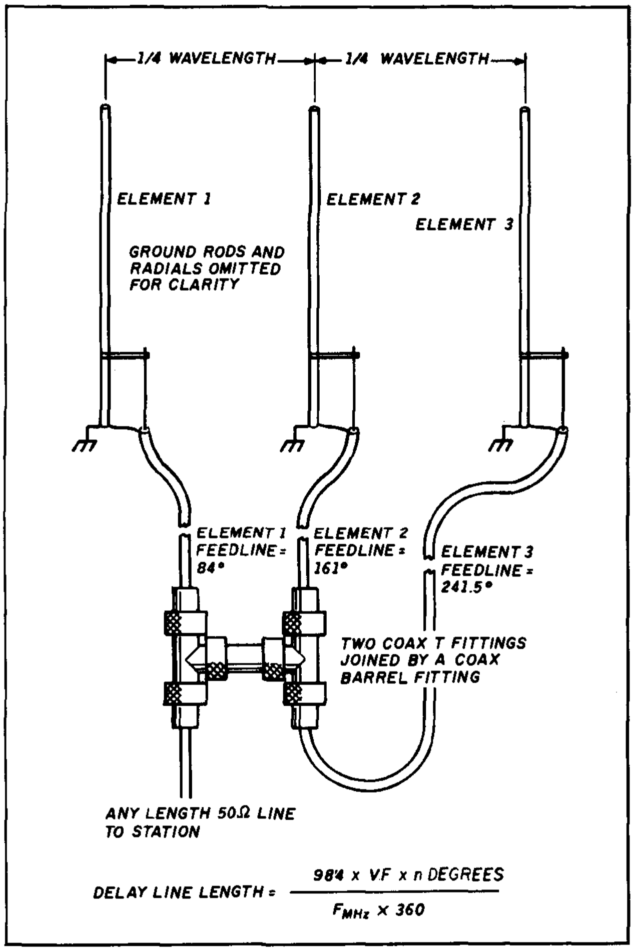
Element lengths

Antenna elements constructed of tubing should be slightly shorter than quarter-wavelength elements made of wire. The formula $230/F_{MHz}$ results in element lengths of 8 feet at 28.5 MHz, which will provide a reasonably low VSWR over the entire 10-meter band. After the elements have been cut, deburr the cut ends with a file and drill four evenly spaced 3/32-inch holes around the circumference and 1/4 to 1/2 inch from one end of each element. You'll attach the radials and coax connectors at these points later with no. 6 self-tapping sheet metal screws.

Gamma rods

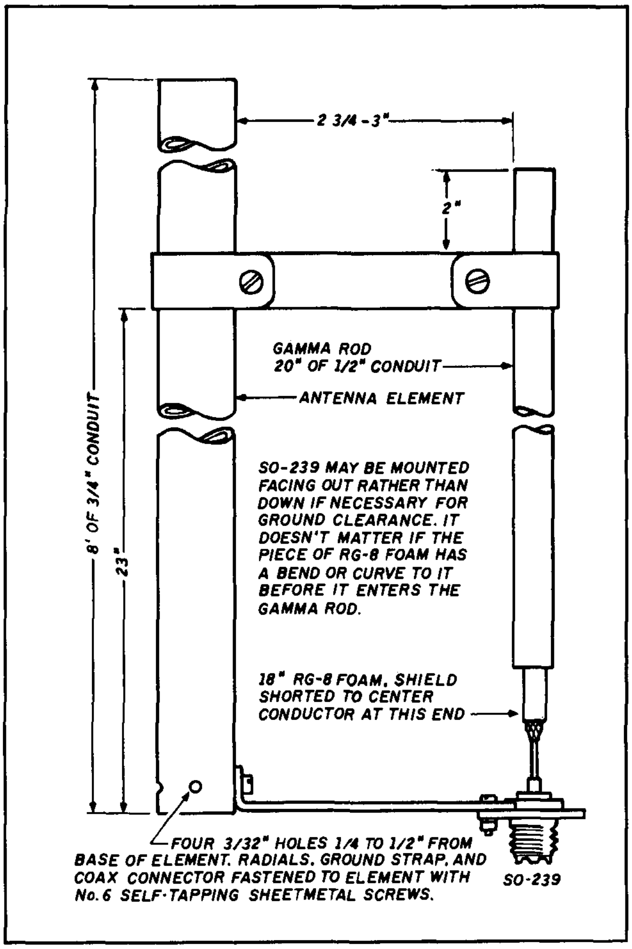
The gamma rod and variable gamma capacitor for each element consists of a 20-inch piece of 1/2-inch conduit, an 18-inch piece of RG-8 foam dielectric coaxial cable, four conduit straps, and an SO-239 female coaxial cable connector. Cut and deburr the piece of conduit, then strip 1.5 inches of insulation from one end of the piece of RG-8 foam coax. Fold back the braid and remove 1 inch of the center dielectric; then solder the braid to the center conductor. Tape and seal the other end of the cable to prevent moisture contamination. Next, flatten two of the conduit

FIGURE 1



Three-element driven array for 28 MHz. Phasing lines are cut according to formula in text.

FIGURE 2



Assembling gamma rod and antenna element.

straps (a hammer works fine for this). File a notch in the end of one strap so the hole in the strap will mate with one of the holes on the SO-239's mounting flange. Fasten the strap to the connector with a 4-40 screw, lockwasher, and nut as shown in **Figure 3**. Bend the other end of this strap as indicated, and fasten it to the bottom of one element with a no. 6 self-tapping sheet metal screw.

Gamma assembly

Make the shorting bar clamps by straightening the "ears" on the two remaining straps. Slip one modified strap onto the element, slide the other onto the gamma rod, place the remaining previously flattened strap between them (see **Figure 3**), and fasten tightly with machine screws, lockwashers, and nuts. Tighten the screws to form the clamps; they can be loosened for adjustment. Slip the already prepared section of coaxial cable into the gamma rod (don't worry about the sloppy fit — it won't make any difference in performance) and solder the shorted end of the cable to the center conductor of the SO-239.

The gamma rod with the cable inside makes an adjustable tubular capacitor of about 100 pF, which eliminates the expense of finding a suitable transmitting-type variable capacitor and the hassle of building some sort of weatherproof enclosure for each element. Loosen the clamps on the shorting bar and set the top edge of the gamma rod clamp 2 inches from the top of the rod and the bottom edge of the element clamp 23 inches from the base of the element. These dimensions will be your starting points during adjustment and tuneup. Tighten the clamps, set the element aside, and prepare identical matching sections for elements 2 and 3. It should take only a couple of hours to build all three elements.

Element mounting

The elements should be spaced a quarter wavelength apart using the formula $246/F_{MHz}$ (8 feet, 7 inches at 28.5 MHz), and mounted so they are in line with the compass bearing you wish to favor. I put mine on a wooden picket fence running due east and west; this gives me good coverage of Europe and Africa in one direction, and Australia and Japan in the other. As the main lobe is fairly broad, precise aiming isn't necessary with this array. The elements are fastened to the fence with conduit straps and wood screws. If you don't have a handy wooden fence running in the right direction, you can fasten the elements to wooden posts set deep enough to ensure that they won't topple over if disturbed.

The importance of a good ground system

I can't overemphasize the importance of a good ground system for this or any other type of ground-mounted vertical array. Remember the efficiency of a grounded vertical antenna is directly related to the quality of its ground system. This array *will* radiate with no ground system at all (although it will be difficult to tune) and will still provide about 4.5 dB of gain, but that gain is referenced to a single *similar* element. The efficiency of a quarter-wavelength vertical over poor ground may be 25 percent or less, which means that a poorly grounded array of this type would barely achieve the efficiency of a single horizontal dipole.

Ground losses

The ARRL Antenna Book lists the loss resistance for a quarter-wavelength vertical with only four radials as 29 ohms! Because loss resistance is added in series to radiation resistance, four radials on a vertical is equivalent to putting a 30-ohm resistor in series with your feedline. Eight radials drops the loss resistance to 18 ohms, while 16 radials lowers it to only 9 ohms. While this isn't ideal, it's a figure most of us can live with.

An ideal ground system would consist of 120 or more quarter-wavelength radials fanned out equally around the base of each element, but a reasonable compromise can be achieved using a ground rod and 16 quarter-wavelength radials for each element. Obviously, the more radials the better, with 16 per element as a minimum starting figure. However, if you decide to install more than 16 radials, remember that you'll need to double the number of radials *per element* to achieve any appreciable reduction in ground loss. The next step up from 16 would be 32 radials, and the step after that would be 64 — that's a total of 192 radials!

The ground screen

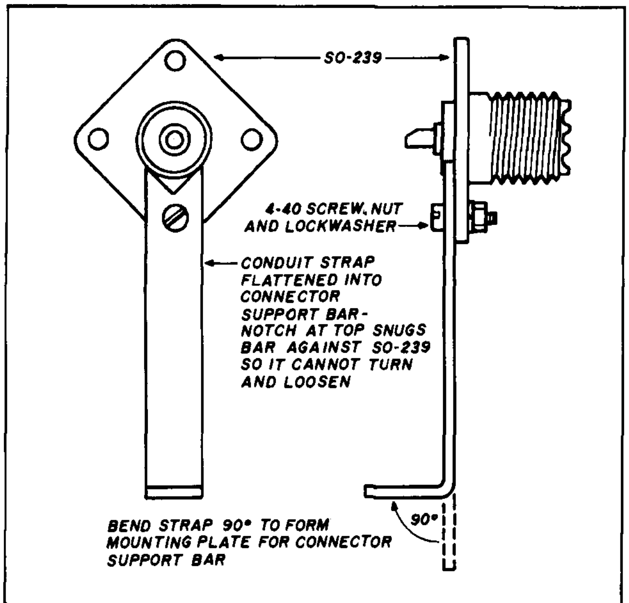
An alternative to installing a radial system is to use metal screening or hardware cloth. As long as all the joints are bonded together electrically, you can lay the metal mesh directly on the ground, secure it, and let the grass grow up through it. Eventually you won't even be able to tell it's there. Such a ground screen should cover the area immediately under the array and extend a quarter wavelength from the sides and ends. Individual strips of screening material must be soldered or welded to adjoining strips every few inches. That much hardware cloth (nearly 700 square feet) would be pretty expensive, which is why I used radials. But if you happen to have enough screen on hand, give it a try. It will make a nearly perfect ground for your array, and cut ground losses to nearly zero.

Ground rod and radial construction

Each element in my array has its own ground rod made from 4-foot pieces of steel reinforcing rod (rebar), hammered into the ground at the base of the element until only the top 2 inches stick out. Perhaps copper ground rods would be better, but rebar is cheap, durable, and readily available in my area. You could also use 4-foot sections of conduit in place of the rebar. Longer ground rods might be better, but 4-foot rods are difficult enough to drive into the soil. Bond the ground rod to the base of the element with a short piece of heavy wire or braid.

The quarter-wavelength radials are cut to the formula

FIGURE 3



Connector support bar is fashioned from conduit strap.

$234/F_{MHz}$, which makes them 8 feet, 2-1/2 inches long at 28.5 MHz. I used inexpensive four-conductor telephone hookup wire because I had it on hand, cut four sections for each element to the proper length, separated the four wires in each section from their outer covering, and fastened them to the bottoms of the elements with ring connectors and sheet metal screws. Any wire of any size will do, as long as the radials are close to the right length. Ideally, the radials should be fanned out around the base of each element evenly; however, if you don't have the space, don't worry too much about it. There will be some pattern skewing in the direction of the greatest number of radials, but the array will still function just fine. Some people like to bury their radials; I use U-shaped pieces of stiff wire (ordinary bobby pins work well) to peg the radials to the ground at approximately 1-foot intervals, so people won't trip over them.

Phasing lines

As shown in **Figure 1**, the phasing or delay lines for this array are brought to a common point and connected together by a "plumber's delight" arrangement of two coaxial T fittings joined by a coaxial barrel connector One feedline of any length of 50-ohm coax goes to the station. I recommend Belden 9913, RG-8 Foam, RG-8, or RG-8X for long runs. Stay away from RG-58 unless the transmission line going to your shack is shorter than about 50 feet. Cut the remaining three feedlines to the elements so that element 2 is 90 degrees out of phase with element 1, and element 3 is 180 degrees out of phase with element 1. Cut the phasing lines according to the formula:

$$\frac{984 \times VF \times n \text{ degrees}}{F_{MHz} \times 360} \tag{1}$$

where VF = the velocity factor of the coaxial cable used.

This gives you the *electrical* length of a piece of coaxial cable n degrees long. Thus, element 1 is fed with a 90-degree (quarter wavelength) section of coaxial cable; element 2, if it is to be 90 degrees out of phase with element 1, requires a 180-degree section (half wavelength); and element 3, which you want to be 180 degrees out of phase with element 1, takes a 270-degree section (three-quarter wavelength). However, since there's mutual coupling among the elements in the array, the line lengths must be adjusted from these values somewhat to provide a proper feed. The line to element 1 should be 84 degrees long, the line to element 2 should be 161 degrees, and the line to element 3 should be 241.5 degrees long. I used RG-8X coaxial cable, which has a velocity factor of 0.75, to construct my delay lines. The feedline for element 1 is 6 feet, for element 2 it's 11.5 feet, and for element 3 it's 17 feet 4 inches. These lengths include the coaxial connectors at the ends of each feedline. If you use a different type of coaxial cable, with a different velocity factor, you'll have to refigure the feedline lengths. Chapter 24 of *The ARRL Antenna Book* lists the velocity factors of popular coaxial cables.

Adjustment

Before you connect the phasing lines to the elements, you must first tune each element to resonance. Without a feedline attached to either element 2 or 3, but with all three elements mounted in place, connect a VSWR bridge to the base of element 1 directly through a short piece of 50-ohm coax, and connect the meter to your transceiver through the feedline you'll use to drive the array. Adjust the position of the clamps on the element and gamma rod for lowest VSWR (making sure the transmitter is off while you work on the antenna, of course).

Obtaining lowest VSWR

First move the shorting bar up and down both the element and the gamma rod in small increments, until you reach the point of lowest VSWR. Then move the gamma rod only up and down in its clamp (this adjusts the variable capacitor) to bring the VSWR down further. By alternating these adjustments — first the shorting bar, and then the gamma capacitor, you should be able to find a point where the VSWR is nearly 1:1. Once you've found this point, tighten the clamps securely, and repeat the procedure for each of the other two elements. Go back and check that element 1 is still in tune. (Remember, there's mutual coupling among the elements and all adjustments are somewhat interdependent.) Repeat these adjustments until each element's VSWR is as close to 1 as possible.

Now connect the three delay lines to the elements, and their opposite ends to the main feedline, as shown in **Figure** 1. Apply power to the array. The VSWR at the station should be around 1.5:1. If it isn't, and all the elements are close to 1:1 at their feedpoints when tuned individually, you can feed the array through a matching network located at the transmitter end of the feedline to make your transistorized finals happy. Tuning will differ from one installation to another, depending upon ground losses, proximity to nearby conducting objects, and the number of radials attached to each element.

That's all there is to it. The direction of maximum radiation or reception will be in line with the array from element 1 to element 3. To switch the direction of the array, simply connect the feedline of element 1 to element 3, and the feedline of element 3 to element 1.

Performance

I don't have an antenna range, but on-the-air tests comparing the array with a 10-meter dipole at 35 feet indicate that the array beats the dipole by a minimum of 1 to 2 S-units — and sometimes (especially if the other station is using vertical polarization) by as much as 4 to 5 S-units. The low angle of radiation presented by vertical antennas helps on those long DX contacts, and the vertical array seems less susceptible to atmospheric noise than the dipole — although it is more susceptible to manmade noise. Stations off the back of the array are typically 4 to 6 S-units weaker than with the dipole, which helps when you're trying to pull a weak one through QRM.

Adding more elements

I like a three-element design for this array because of its broad main lobe, and because it simplifies beam pattern switching. I just have to swap the feedlines to elements 1 and 3 to "turn" the beam 180 degrees. However, if you wish to work in one direction only, or if you don't mind changing several different feedlines, there's no reason why you can't add more elements to this array. The theoretical gain of an array of this type is 10 log(N), where N equals the number of elements. Thus, maintaining quarter-wavelength spacing between elements, an array with four elements would have a gain of 6 dB, five elements would give you 7 dB, and six elements would give 7.8 dB over a single similar element. Actual gain figures will, of course, be slightly lower, depending upon ground losses, feedline losses, and proximity to nearby objects. Remember that adding elements will narrow the beamwidth, which will make aiming the beam more critical.

The effects of mutual impedance among the elements become more critical as the number of elements increases; so do delay line losses. You'll want to use only high quality, low loss coax for your delay lines, and you'll probably want to use the current-forcing method of feeding multi-element arrays described in Chapter 8 of *The ARRL Antenna Book*. However, the math and measurements involved in using the current-forcing method are quite cumbersome. If you're in the mood to experiment, you might try delay line lengths of 322 degrees for element 4, 402.5 degrees for element 5, and 483 degrees for element 6.

I'd be interested in hearing from others who build this array — especially from those who adapt it to other bands, or add additional elements.

AN EXCLUSIVE LOOK AT KENWOOD'S TS-950S

J. Craig Clark, NX1G, Assistant Publisher, Ham Radio Magazine

One of the best parts of Amateur Radio publishing is getting a chance to go behind the scenes of new product development and marketing. Recently I was offered a good look at Kenwood's new addition to their HF line — their just-announced TS-950S. Here's a preview of the features and preliminary specifications of this new transceiver.

The basics

The engineers at Kenwood have really worked overtime (and then some) to design this new radio. The TS-950S is a 10 through 160-meter Amateur transceiver plus a general coverage receiver from 100 KHz to 30 MHz. The transmitter section is rated at 150 watts output on all Amateur bands. The TS-950S has dual receive capability and incorporates the latest digital filtering techniques in both its transmitter and receiver.

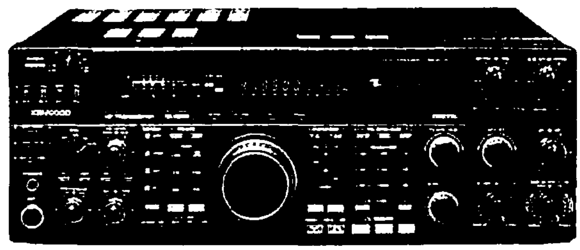
Kenwood called a short time ago and gave me some exclusive information on the new TS-950S transceiver. You can imagine the excitement it created here at *Ham Radio* as we conjured up all kinds of design ideas and operational capabilities over a lunch of burgers and fries.

Then Kenwood faxed us the preliminary technical specifications, operational capabilities, and other design features. We pored over the "top secret" material anxiously to see how close we had come to predicting what the TS-950S could do and how it compared with other radios. We certainly weren't disappointed.

New features

One of the radio's most interesting new features is Kenwood's Digital Signal Processor (DSP). The DSP is designed to take advantage of the latest state-of-the-art signal processing techniques. Kenwood's new DSP technology allows the following ratings for the TS-950S: spurious response less than 50 dB, unwanted sideband suppression less than 60 dB, and carrier suppression of greater than 50 dB. These numbers are 10 dB better than can normally be achieved with analog signal processing. This should be a major step forward in reducing unwanted clutter and noise on the Amateur bands.

The DSP also allows flat and clean transmit audio over four user-selectable ranges. Emphasis can be either added or subtracted, based on operator preferences and individual voice characteristics. Digital tailoring, as opposed to brute force analog processing, is expected to result in a much cleaner transmitted audio signal. This can be the margin of difference in intelligiblity under crowded bands conditions.



Code operators should find the CW waveform quite pure and free of any spurious signals. The waveform rise time is user selectable in either fast or slow modes. Finally, the DSP gives you a digital AF filter. The AF filter is synchronized with the SSB IF slope-tuning controls to improve slope-tuning filter response characteristics.

Another neat TS-950S feature is its dual receive capability. The TS-950S lets you listen on two separate frequencies (within 500 KHz of each other) simultaneously.

A separate IF circuit for the subreceiver minimizes problems even under the most adverse operating conditions. Frequency selection is separate from the main receiver and is available in either 10 or 100-Hz steps. The subreceiver also has a noise blanker control that's independent of the main receiver settings. The audio level is continuously variable and the subreceiver has a florescent tube display of its own.

Kenwood has also redesigned the final amplifier circuit to take advantage of high output, 50-volt, low noise RF transistors. Consequently, you should never find yourself running short of sufficient drive for any amplifier you may have. The final deck is mounted on a large aluminum heat sink and has a thermally switched fan.

The automatic antenna tuner is a nice little extra. It's controlled by its own microprocessor and preprogrammed with band settings to reduce tuning time.

In addition to using digital signal processing, the receiver section has a redesigned front end with a cascode amplifier circuit (or source floor circuit). The signal is fed into the first of two double balanced mixer circuits. This technique is used to reduce the noise floor substantially and improve two-tone characteristics. The IMD is claimed to be less than −37 dB with an intercept point of +20 dBm, a dynamic range of +105 dB, and a noise floor of −140 dBm.

The TS-950S's filtering is very similar to the earlier Kenwood HF radios with SSB IF slope tuning, CW VBT, AF tune audio filter, and an IF notch filter. In CW and RTTY modes

TS-950S preliminary engineering specifications

General

Transmitter frequency range	160-meter band 1.8 to 2.0 MHz 80-meter band 3.5 to 4.0 MHz 40-meter band 7.0 to 7.3 MHz 30-meter band 10.1 to 10.15 MHz 17-meter band 18.068 to 18.168 MHz 15-meter band 21.0 to 21.45 MHz 12-meter band 24.89 to 24.99 MHz 10-meter band 28.0 to 29.7 MHz
Receiver frequency range	100 kHz to 30 MHz
Mode	J3E(SSB), A1A(CW), F1B(FSK), F3E(FM), A3E(AM)
Temperature range	14°F to 122°F
Frequency stability	$\pm 0.5 \times 10^{-6}$
Frequency accuracy	$\pm 10 \times 10^{-6}$ (at normal temperatures)
Antenna impedance	50 ohms
Power requirements	120/220/240 volts AC, 50/60 Hz
Power consumption	Maximum transmit 700 watts. Receive (no signal) 80 watts
Dimensions	15.83" W × 5.55" H × 15.75" D (projections not included)
Weight	40.78 pounds (approximately)

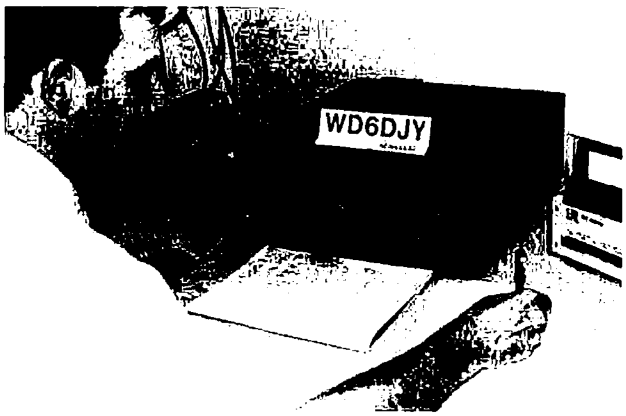
Transmitter

Final power output	SSB/CW/FSK/FM = 150 watts PEP, 10 meters: 110 watts
Modulation	SSB = balanced modulation, FM = reactance modulation, AM = low level modulation
FM maximum:	
Frequency deviation	±5 kHz
FSK shift width	170 Hz
Carrier suppression	Less than −50 dB
Spurious response	Less than −40 dB (CW)
Unwanted sideband	
Suppression	Better than 60 dB (modulation frequency—1.5 kHz)
Third Harmonic	
Intermodulation distortion	Better than −37 dB (at 14.2 MHz) (based on single tone output)
Microphone impedance	500 to 50 k ohms
Frequency response (SSB)	200 to 3100 Hz

Receiver

Circuitry	Quadruple conversion system
Intermediate frequency	1st IF—73.05 MHz 2nd IF—8.83 MHz 3rd IF—455 kHz 4th IF—100 kHz (except FM)
Sensitivity	SSB,CW,FSK: Less than 2.5 µV (100 to 150 kHz) (at 10 dB S/N) 1 µV (150 to 500 kHz) 4 µV (500 kHz to 1.62 MHz) 0.2 µV (1.62 to 30 MHz) AM: Less than 25 µ (100 to 150 kHz) (at 10 dB S/N) 10 µV (150 to 500 kHz) 32 µV (500 kHz to 1.62 MHz) 2 µV (1.62 to 30 MHz) FM: 12-dB SINAD less than 0.5 µV (28 to 30 MHz)
Squelch sensitivity	SSB,CW,FSK,AM. Less than 6.2 µV (100 to 150 kHz) 2.5 µV (150 to 500 kHz) 10 µV (500 kHz to 1.62 MHz) 0.5 µV (1.62 to 30 MHz) FM: Less than 0.32 µV (28 to 30 MHz)
Image ratio	More than 80 dB (1.8 to 30 MHz)
IF rejection	More than 70 dB (1.8 to 30 MHz)
Selectivity	SSB,CW,FSK 2.4 kHz (−6 dB) 3.8 kHz (−60 dB) AM: 6 kHz (−6 dB) 15 kHz (−60 dB) FM: 12 kHz (−6 dB) 24 kHz (−60 dB)
Variable frequency range	SSB slope tuning (with SSB filter) High cut = more than 1500 Hz Low cut = more than 700 Hz CW VBT (without optional filter) 600 Hz to 2.4 kHz (continuous)
RIT/XIT variable range	±9.99 kHz
Notch filter attenuation	More than 45 dB
Audio output power	1.5 watt (8 ohms at 10 percent distortion)

Specifications are subject to change on production radios without notice.



the AF VBT lets you tune the audio passband away from interfering signals.

An interesting new feature gives you the ability to select second or third IF filter combinations independently, based upon conditions, and save them in memory with the operating frequency. This conserves time when changing bands or modes.

Visit to Kenwood

Several days after receiving the preliminary specifications on the TS-950S from Kenwood, I was in Los Angeles and had an opportunity to sit down and spend a few hours operating this new radio.

The basic layout of knobs, buttons, switches, and other controls is very similar to earlier Kenwood models. It took me just a few minutes with the user's manual to learn how to operate the TS-950S. However, I quickly found that it would take a little extra time to become acquainted with some of the new features and ascertain the radio's true power.

One of the first things I noticed is that Kenwood has gone to a bar graph readout, as opposed to the analog meter movement found in other radios. The indicator shows signal strength, final current, SWR, compression, ALC level, and power output.

The filter selection readouts are located next to the bar graph. The first IF (8.83 MHz) filter lights are on the left; the

(continued on page 80.)

ARTIFICIAL INTELLIGENCE APPLICATIONS IN AMATEUR RADIO

Make your computer think for you!

By Bryan Bergeron, NU1N, 30 Gardner Road, Apt. 1G, Brookline, Massachusetts 02146

Since their introduction a little over a decade ago, microcomputers have been applied to virtually all phases of Amateur Radio — from modeling the ionosphere to predict HF propagation; calculating antenna radiation patterns; generating and interpreting CW, RTTY, and SSTV; to satellite tracking and circuit design. In general, these and other Amateur Radio applications use complete, step-by-step algorithms for problem solving. For example, when you know the DC voltage and resistance, you can calculate the current using Ohm's Law, I=E/R.

However, there are problems in Amateur Radio that don't lend themselves to simple algorithmic solutions; they are non-numeric and ill defined. For instance, if your receiver suddenly exhibits reduced audio output, what's the most likely point of failure? Is it the power supply? Perhaps it's the RF amplifier? Suppose you have both vertical and dipole antennas, and you want to contact Canada. Assuming the same working frequency, which antenna should you use? What if there's snow on the ground? What if it's summer...or winter? Diagnosing transceiver and antenna failures, and complex propagation predictions are but a few of the problems in Amateur Radio that defy simple numerical analysis. I'd like to tell you about expert systems — a class of "Artificial Intelligence" (A.I.) software tools developed expressly for non-numeric problems — and their Amateur Radio applications.

Some expert system basics

A.I. is a branch of computer science devoted to investigating robotics, vision, speech recognition, and machine intelligence. Expert systems are one of the more commercially viable offshoots of the last decade of A.I. research. Current expert system research is concerned with replacing scarce, expensive human experts with readily available, inexpensive computer "clones," which possess the problem-solving abilities of the human experts. These expert systems are appealing because they provide instantaneous advice. The system asks only for the data it deems necessary to solve the particular problem it's presented.

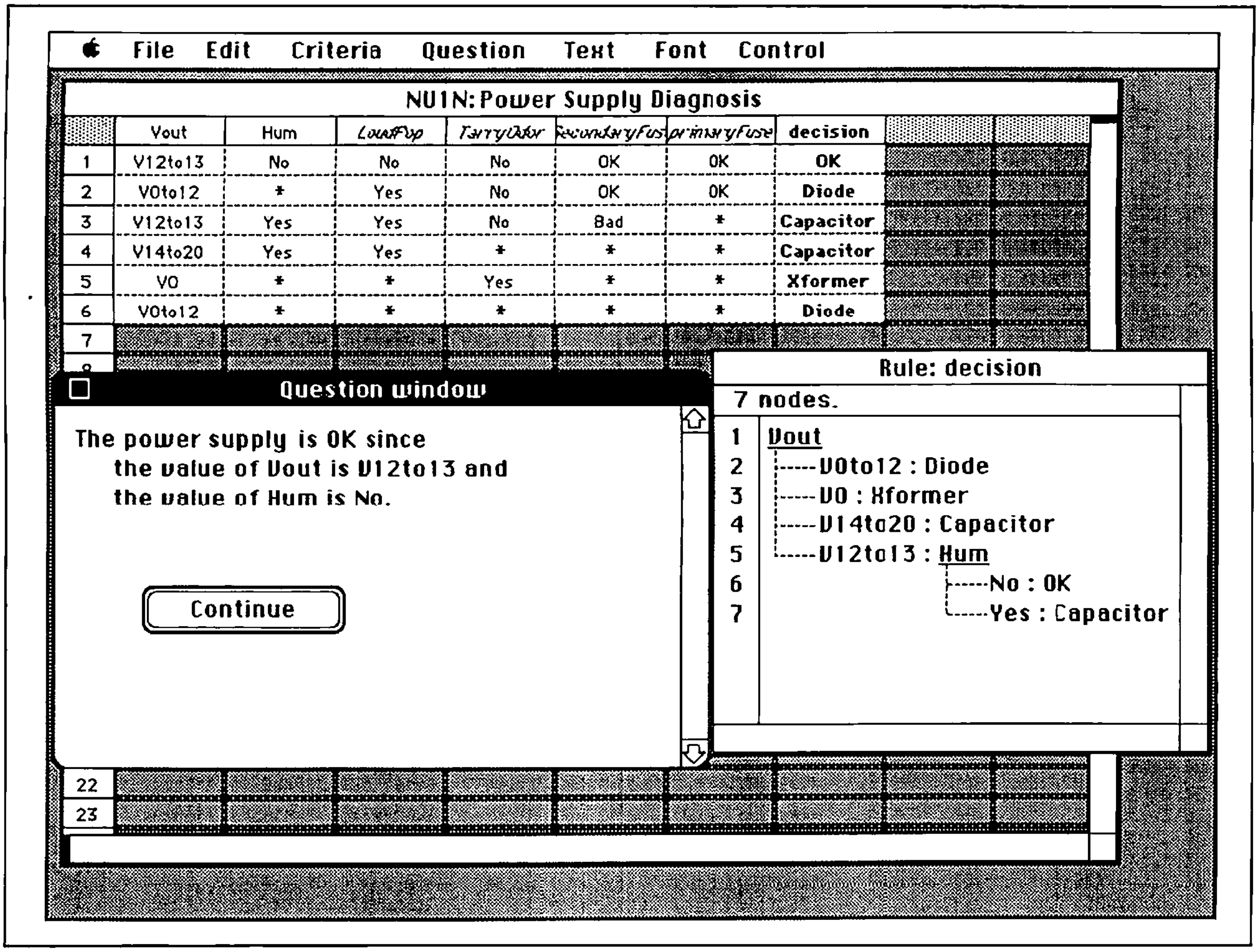
You can think of an expert system as a program composed of two major interdependent modules. First, it's an inference engine or rule interpreter for defining rules specific to the problem area. The inference engine is also responsible for informing the user of the conclusions that have been reached. Second, it's a knowledge base, which usually takes the form of rules. An example of a rule from a knowledge base dealing with power supply diagnosis might read:

IF the output voltage is zero, AND there is a strong odor like burning tar, THEN the power transformer is suspect.

Notice that, for the most part, this rule isn't numerical. Rules are typically composed of simple, English-like statements. The premise (the IF and AND parts of a rule) is always followed by a conclusion (the THEN part of a rule).

The rules in a knowledge base are generally constructed by interviewing a human expert and determining what heuristics (rules of thumb) he or she uses in solving specific problems. Capturing the human expert's heuristics is the point of expert system programming. Consider, for example, how a novice technician might go about troubleshooting a particular power supply. He first checks the fuses, then the transformer, and so on, in some sort of systematic fashion. The expert technician, with years of experience repairing the same model power supply, checks the rectifier bridge immediately. Based on past experience, the expert knows that on power supplies of this design, the rectifier bridge is the most likely point of failure. Now, if the novice technician works long enough with the expert, he, too, will learn the rules of thumb for each piece of equipment. Unfor-

FIGURE 1



An expert system shell programmed for power supply diagnosis. The "source code" for this greatly over-simplified expert system takes the form of examples in the spreadsheet-like window (background, center). The decision rules to be used by the expert system during a consultation (right, foreground) are derived automatically from programmer-suppled examples. The Question Window, the only window normally seen by the user, currently displays the results of a previous consultation (left, foreground).

tunately, not all of us have the opportunity or time to work with experts in every field. Hence the beauty of expert systems!

Expert system development alternatives

How do you go about developing an expert system? You can start with a traditional, procedural language like BASIC or PASCAL, a nonprocedural "A.I. language" like LISP (LISt Processing), or with an expert system shell. Although it's possible to create suitable inference engines with BASIC or PASCAL, it requires a great deal of time and experience with A.I. techniques like recursion (when a routine repeatedly calls itself). Handling lists of text and implementing recursion are almost trivial in LISP, but you must learn to program in LISP or some other A.I. language. Unless your goal is to learn A.I. techniques, an expert system shell is the way to go.

Shells provide the quickest and easiest means of creating an expert system. These shells are available for virtually all microcomputers, at prices ranging from $49 to over $5000. There are at least half a dozen shells available for the Commodore-64, Apple II, IBM PC, and Macintosh computers for less than $200. My favorite shell for the IBM PC is VP-Expert™ from PaperBack Software, at less than $100. For the Macintosh, I use SuperExpert™ from Softsync, at about $150.

Expert system shells provide a programming environment that includes everything you need to create an expert system, with the exception of a knowledge base. Shells typically provide not only the inference engine, but also an editor for entering rules, some sort of end-user interface, and software tools for maintaining the knowledge base. If you can write simple IF/THEN rules, like the ones in my example, you can program an expert system shell. It's that simple!

If you have trouble writing simple rules, or the rules aren't readily apparent, or there are simply too many rules to keep track of, there's still hope. So called "case-based" expert

shells are available (see Figure 1). These shells take files of expert decisions and derive executable rules from these examples through a process called induction.[1] Expert system shells that make use of case-based programming (sometimes called "programming by examples") have the potential to make an important contribution to Amateur Radio. Expert systems developed using this programming approach are already being used in law, medicine, and military science.

Some expert system applications

Expert systems have been developed by the military to help diagnose problems in electronic circuitry,[2] by NASA to help shuttle pilots land,[3] and by physicians to help diagnose patients.[4] What can you, as an Amateur Radio operator, do with expert system technology? As an explorer of this exciting, new frontier, you are limited mainly by your imagination. Here are two systems that I've developed out of necessity and curiosity. Each system took me less than a day to create with the aid of a shell. You'll no doubt see ways to improve upon these systems, or devise even more sophisticated ones to suit your own needs.

Transceiver diagnosis

My wife, KA1SSL, doesn't have my background in electronics or 20 years experience in Amateur Radio. However, she's very active and is learning all aspects of the hobby — including equipment repair. To give her a hand while I'm away on business trips, I created an expert system (using the programming by examples shell SuperExpert on the Macintosh) to aid in diagnosing our SWAN-500 transceiver. Using the case-based approach, I created a knowledge base that included the most likely points of failure (antenna down, bad coax, blown finals, faulty power supply, keyer defective) and methods of remedying them. My wife thinks the system is great! You might consider a similar project if your husband, wife, or children are new to Amateur Radio equipment diagnosis.

Antenna selection

Like a number of Amateurs, I'm not fortunate enough to have the real estate required to erect a seven-element Yagi. Instead, I make do with a multiband vertical and a dual band dipole. I've come to realize that the performance of each antenna varies considerably, depending on the season, weather, and location of the received station. The dipole, for example, performs poorly in the rain (not surprising in retrospect, since it is run between closely grouped trees), whereas the vertical performs superbly (perhaps because of the increased efficiency of the ground system). Again, using a case-based expert system shell, I managed in just a few hours to create a useful expert system to aid in antenna selection. For the most part, I took the cases I used to program the shell directly from my logbook, where I record the time, frequency, weather conditions, QTH, signal strength, and antenna used for each contact. Patterns that may not be obvious from casual observation of logbook data (e.g., when there's snow on the ground, and my objective is to work Europe, the dipole is the better choice), may be revealed by a case-based expert system. Your logbook is likely harboring similar surprises!

The future

What does the future hold for expert system technology and Amateur Radio? I'd like to see expert systems available — either as shareware or at a nominal fee — to aid in the construction, diagnosis, and use of all Amateur equipment. Diagnosis of antenna failures and problems with power supplies, today's ultra-complex transceivers, and keyers could all be much less time consuming if expert systems were readily available. How about a system to select toroids for your next project? And wouldn't it be great to have a system that, if given the desired noise characteristics and frequency range of a preamplifier, could tell you which field effect transistors you should use? Imagine the impact on Amateur Radio if, in each Amateur Radio club, the gurus got together and created expert systems for the other members. It's up to you. Amateur Radio is about communications and sharing. Expert systems seem to be a natural extension of our desire to explore and communicate. hr

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Ham Radio Techniques

Bill Orr, W6SAI

INTERESTING ANTENNA FEED SYSTEMS

In my August column, I discussed the gamma match — a convenient and easily adjustable device for matching a coax line to the driven element of a Yagi beam. Many commercial beams use this system.

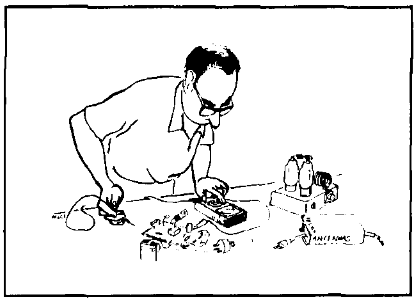
Other interesting but less well-known matching systems exist; I'll cover a few that the homebrewer can use. Some of the matches will function with a multi-band antenna, while others are single band devices. All of them deserve consideration for your next antenna project.

The W6GKM matching system

Back in 1950 Dale Frink, W6GKM, devised a match for his 10-meter beam.[1] The arrangement is shown in **Figure 1**. The driven element is split with a 2-inch gap at the center, and excited by a length of 50-ohm coax. The inner and outer conductors are shorted together at each end of the coax, and the shield braid is broken and fed with the transmission line at the center. The "matching coax" is about one-quarter wavelength long.

Dale taped the matching coax to the driven element, taking care that the ends of the coax didn't short to the driven element. He found the SWR was low over the entire 10-meter band. Dale told me that he'd also placed the matching coax inside the driven element, instead of taping it to the outside. It seemed to work equally well either way.

How does this device function? The driven element is split and there are no electrical connections to either half. The simplest explanation is that the capacitance between the matching coax and the dipole halves does the job.

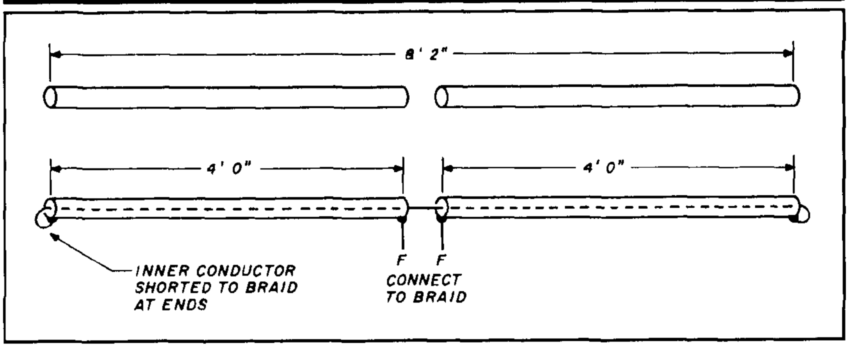


The Mosley "Classic" match system

The Mosley "Classic" series of antennas use a similar matching scheme.[2] This device is shown in **Figure 2**. The Mosley advertisement calls it a "balanced capacitive match." The Classic match resembles the system used in W6GKM's design. Even though Dale uses coax in his match, the only meaningful part of the match is the outer shield of the coax — the inner conductor contributes nothing. By substituting a single insulated wire for the coax, you have the Classic system instead of the W6GKM match.

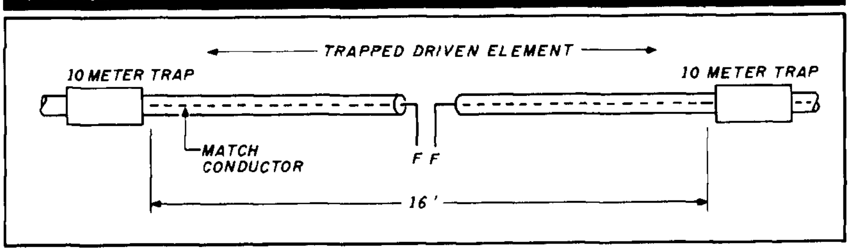
With the Classic-33 tribander, the match conductor is about a quarter wave long on 20 meters. It's placed inside the split driven element. I'll accept that; but how does the match function on the 15 and 10-meter bands, where the match wire is longer than a quarter wavelength? Is the length of the match wire unimportant, or does it bear a specific relationship to the operating frequency? I know the match works because I have a Classic-33 beam. It has a good front-to-back ratio, a good operating bandwidth, and exhibits a low SWR value at resonance on each of the three HF bands (10, 15, and 20 meters). Those are the principal attributes of a good match-

FIGURE 1



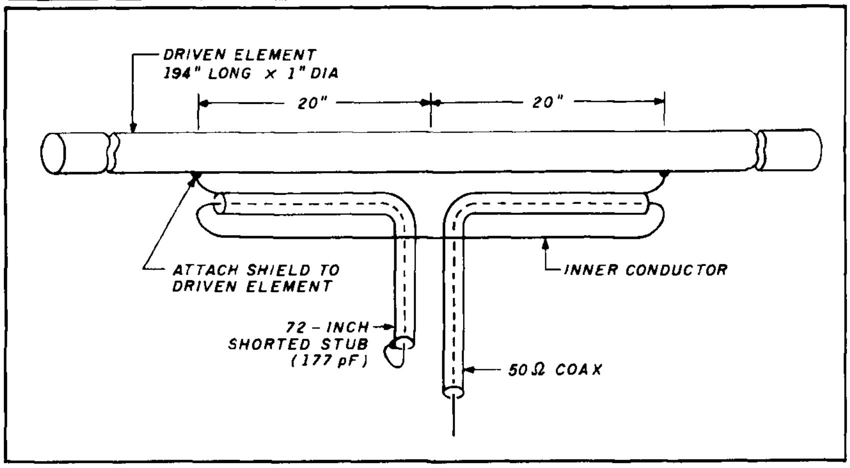
W6GKM feed system. Matching coax is taped to element. Feedline is connected to braid at F-F.

FIGURE 2



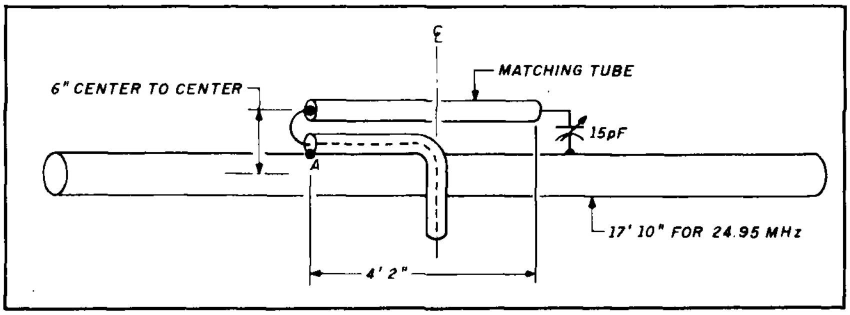
"Classic" feed system consists of coaxial wire placed in each half of trapped driven element.

FIGURE 3



"Clemens match" for 29 MHz. Two gamma matches back-to-back?

FIGURE 4



ZL2ANT version of Clemens match. Coax is taped to driven element. Shield is attached to driven element at A and center conductor is attached to matching tube. Tony says system works best when both tubes are the same diameter.

ing system. Is it purely a capacitive match, or do the match wire and the split element form some kind of a coaxial matching transformer?

The Clemens match

In 1951 John Clemens, W9ERN, published a novel match system he had adapted from a television antenna matching scheme.[3,4] He applied the match to a three-element 10-meter beam (**Figure 3**). This wild-looking device taps the outer conductor of the coax feedline on the driven element at a point that provides a good match to the line. The inner conductor is brought back along the driven element to an equivalent point on the opposite side of the element. It's connected to the element at this point through a series capacitor. The capacitance is made up of a section of coax line. The tap points and capacitance value are varied until unity SWR is obtained at the design frequency.

If you use your imagination, you can think of this device as two back-to-back gamma matches. The gamma capacitor is moved from the base of one gamma to the antenna end of the gamma conductor. The gamma "rod" is the 40-inch length of coax conductor running from one tap point to the other. What an interesting idea!

The Clemens match sank into oblivion for decades. I forgot about it completely until I worked Tony, ZL2ANT, a few days ago. He had taken the 1951 design and modernized it (**Figure 4**). Tony jettisoned the coax and substituted an aluminum tube. He fed the tube and one side of the driven element with the coax feedline taped along the driven element. With the dimensions shown, his series capacitor was 15 pF, as opposed to the 177 pF of the W9ERN design. He feels the 6-inch separation between the matching tube and the driven element accounts for this difference. Tony says the match is very broad and he can work the dipole on both the 10 and 12-meter bands, with low SWR on each band.

All of these designs show the promise of multiband operation. In fact, multiband operation is proven with the Mosley Classic match. Perhaps one of these ideas is the one for you!

The Weinschel matching system

In 1972 *QST* published a triband beam that uses a trapped 20/15 meter driven element connected in parallel with a 10-meter element placed about 18 inches away (**Figure 5**).[5] The elements are connected by double wires, and the combination is fed at the center of the 10-meter element. The product review reported very low SWR on all bands, and the antenna exhibited good front-to-back ratio. I don't know of anyone who has tried this multiband matching system. I'm eagerly awaiting a missive that will inform me of the actual operating results achieved with this simple design.

The open sleeve dipole system

An unusual dual frequency antenna was developed at Stanford Research Institute in 1950. Its operation was described in a paper by H. B. Barkley.[6,7] Roger Cox, WBØGDF, gives a good decription of the device in Amateur terms in *CQ* magazine.[8]

The device is called an "open sleeve dipole." It consists of a conventional center-fed dipole with two parasitic elements spaced close together on each side. The parasitics are cut to a half-wavelength at some higher frequency (**Figure 6**). The ratio of high to low frequency can't exceed 2:1.

You can make a practical open sleeve dipole for 20/17, 20/15, 15/12, 20/10 meters, or other combinations of frequencies between 14 and 29.7 MHz. The drawing gives dimensions for a 20/10 dipole.

This scheme looks like a quick and painless way to add second band capability to an existing beam. In addi-

tion to the "sleeves," you can interlace the parasitic elements for the higher band between the existing elements. It's worth a try!

The Telex/Hy-gain para-sleeve matching system

Here's a triband antenna which uses the open sleeve dipole concept. A product review[9] says the driven element of the "Explorer 14" beam consists of three elements insulated from the boom. The longer element is trapped for 20 and 15-meter operation. The two short sections spaced close to the driven element act as an open sleeve dipole for 10 meters. The short elements are optimized to provide the best SWR across the 10-meter band. The 15/20 meter element is fed with a "hairpin match," balun, and 50-ohm line. According to the product review, the SWR is quite low at design resonance and the front-to-back ratio is good on each band.

The Telex/Hy-gain TH7DX drive system

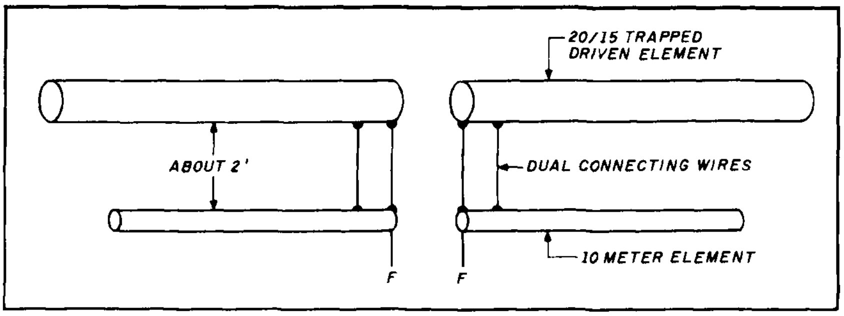
This top-of-the-line triband beam has two trapped, driven elements for 20, 15, and 10 meters. **Figure 7** shows the feed arrangement. The elements are cross connected at the centers and the rear element is fed with a hairpin match, balun, and 50-ohm line. The TH7DX drive system also has very low SWR and good front-to-back ratio at design resonance on each band.

This matching idea resembles the Weinschel system, but uses a cross-over connection instead of a parallel connection between the elements. I wonder about the significance of this difference in connections. The cross-over scheme reminds me of the feed system used on a log-periodic array. Hopefully, someone will come up with a computer program that analyzes these interesting matching systems.

The Log-Yagi design

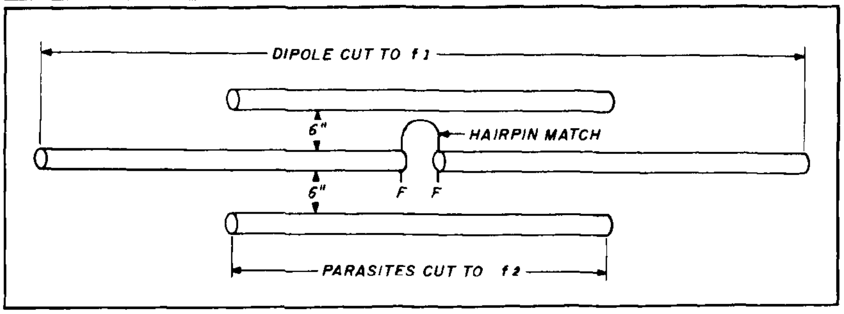
The matching systems I've discussed work on one or more Amateur bands, but it doesn't look as if any of them will cover the five bands between 14 and 29.7 MHz. The log-periodic antenna is the only device that will do this in an acceptable manner. This design trades power gain for bandwidth, and you must put a lot of log-periodic aluminum up in the air to provide equivalent Yagi performance over a wide bandwidth.

FIGURE 5



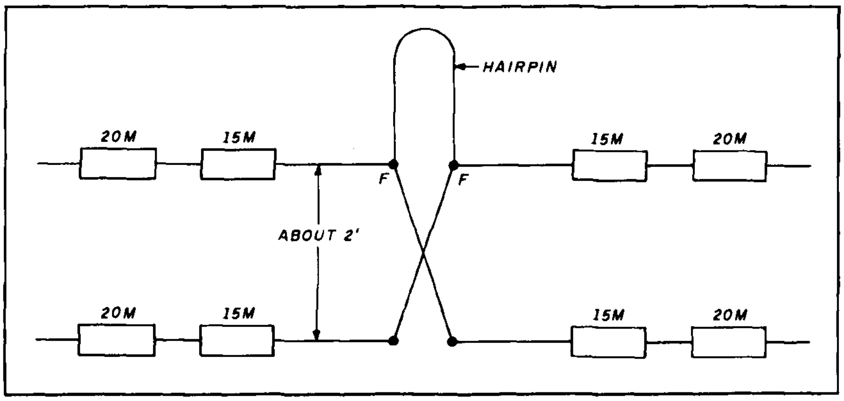
The Weinschel match. Coax balun is used at F-F. Later model beam used "hairpin" match at feedpoint in addition to balun.

FIGURE 6



"Open-sleeve" two-frequency dipole. Spacing between driven element and parasitic element is about six inches.

FIGURE 7



Telex/Hy-gain triband match system using two trapped elements.

There's an interesting derivation of the log-periodic antenna that provides good gain over a single Amateur band when used in combination with Yagi-type parasitic elements. This idea uses a single band log-periodic "cell" of three or four elements, with extra parasitic elements. The technique has been used with single channel TV antennas and is now gaining popularity in Amateur Radio's HF and VHF circles. I discussed this interesting antenna concept in last month's column.

Next month *(if I don't forget), I'll* review the hairpin (inductance) matching technique. It's another way of matching the coax line to the driven element of an array.

The Dead Band Quiz

I thought I had you confounded with the April Quiz about the coax line sections, but a lot of you realized the answer was "zero ohms:"
N1EVN, AB1K, K1REC, WA2DWV, KC2KB, WB2KHE, W2LYH, WB2NTQ,

W2RJW, N3GDE, NK3Z, WX4D, N4DX, W4EIN, WB4HXF, W5DS, K5ESV, K5GV, KA5MXX, W5PEK, K5RA, WB6AWM/7, W6BDN, WB6BYU, WD6DUD, KJ6GR, W6HDO, W6KEZ, ND6M, W6NTX, WA6ZOU, K7FC, W7FSP, WD8KBW, WA8KNE, W8YFB, W9BTI, N9HWC, KS9J/Ø, W9NGP, AAØB, KØLSJ, GØFAH, G4TDJ, VE4KZ.
Congratulations to all!

A thought about the "no-code" license

The May 1989 issue of *The Old Timer's Bulletin* (a publication of the Antique Wireless Association, Inc.) had an interesting comment on the no-code licensing proposal. Bruce Kelley, W2ICE, quotes a reader's suggestion. He makes the argument that the FCC and the ARRL are going about the license enhancement in the wrong way — the code requirement should be retained but the theory should be eliminated! The great majority of hams use factory-made equipment and wouldn't dare touch it if something was wrong for fear of voiding the warranty! They send it back to the maintenance center, and let factory-trained technicians repair it. So why is there a need for technical know-how? Take a look at the February 1988 *Ham Radio* cover, and you'll know what Bruce is talking about! hr

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VARIABLE GAIN
160-METER PREAMP

Tuned input and output offer increased performance

By Gary R. Nichols, KD9SV, 4100 Fahlsing Road, Woodburn, Indiana 46797

After buying a new rig and getting on 160 meters with a shunt-fed tower for my antenna, I soon found myself in the position of most newcomers to top band; I was definitely an "alligator," all mouth and no ears. The shunt-fed tower is great for transmitting, but leaves a lot to be desired for receiving. Quiet is not one of the benefits of a vertical.

Beverage antennas were pretty much out of the question because I live on a fairly small lot (100′ × 300′), so I tried the next best things — small shielded loops, snakes, and short low wires. I had quite a bit of success with the 6′ shielded loop made of 1/2″ hardline and a less than desirable preamp, still managing to work 75 DX countries my first season on the band.

As I looked over the problems I had with a lack of signal when using the loops and intermod on the other antennas, it seemed I needed a good bandpass filter with gain — in other words, a preamp with tuned input and output. After I tried four or five different preamp designs and found them to be lacking either in gain or selectivity, I decided to create my own.

I started with two high Q tuned circuits, matched them for 50 ohms, and then looked for an FET to supply the needed gain. Chuck, N8BYI, had some 3SK88 devices and suggested I try one of them. This device worked very well, producing high gain and a good noise figure.

Circuit description

The circuit (see **Figure 1**) is very basic, except for its unusual bias arrangement. This amplifier's gain is 27 dB typical, and the gain control covers the full range (or more) because of the bias. The 750-k resistor from gate 1 to gate 2 helps to increase the maximum gain. The resistor from gate 1 to the junction of the gain control pot and the 10-k resistor pull gate 1 up above the source slightly at minimum gain setting; this allows the minimum gain setting to be unity (gain of zero) or below, depending on the value of this resistor. Typical values are from 1 to 3 megs.

This arrangement is most beneficial when there are many strong signals present (like during a contest) and you don't want any preamplification. Placing the amp in the circuit at low or minimum gain adds two high Q tuned circuits, which help selectivity and reduce or eliminate any intermod from broadcast stations or nearby hams.

The amplifier has back-to-back diodes to protect the input during transmit. My own transmit signal hasn't caused me any trouble with receiving antennas as close as 75 feet from my vertical. Tune the trimmers for "your" portion of the band; the bandwidth won't cover the full 200 kHz without swamping the tuned circuits at the expense of gain and selectivity. I tune mine for maximum at 1850 and can use it anywhere in the band with somewhat reduced gain at the high end, where I seldom operate.

This year I have five 800′ Beverages, thanks to a friendly farmer and a 1-1/2″ plastic pipe I had put under the road to gain access to 40 acres east of my QTH. I don't normally need the preamp with these antennas — except when signals are very weak. But there are times when the band is noisy, and the shielded loop and preamp "hears" better than the Beverages.

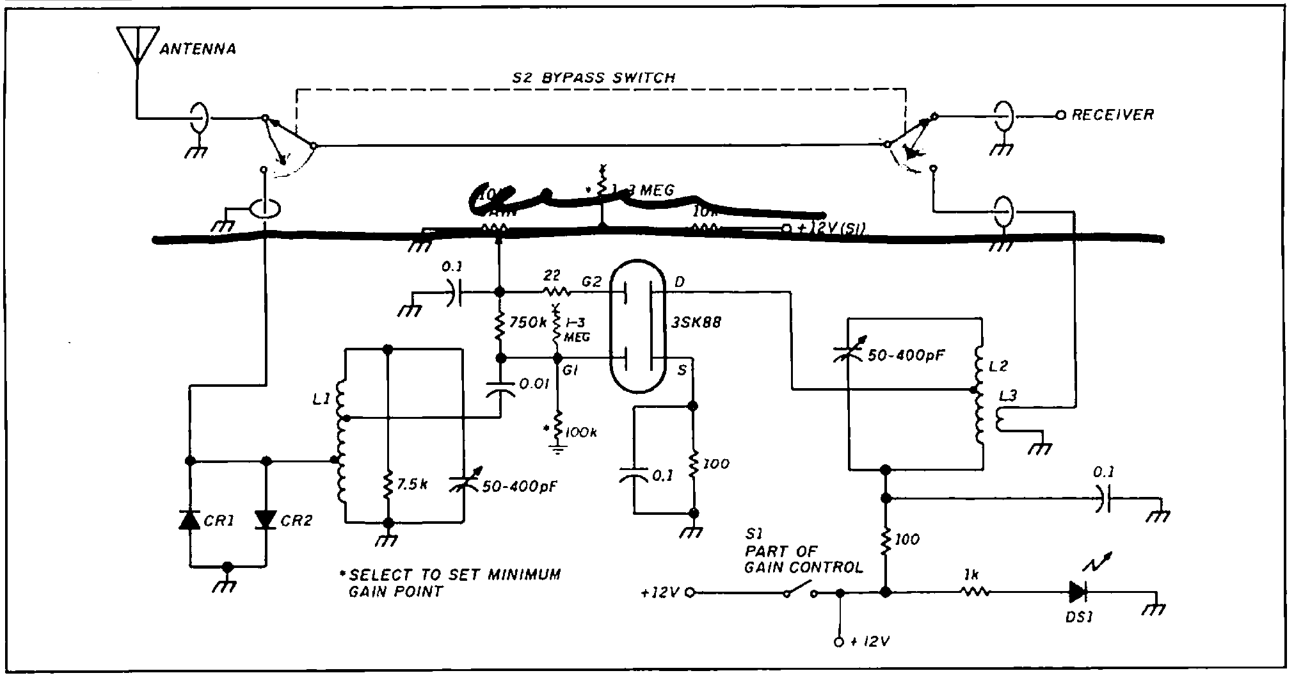
Construction

I built the preamp in a homebrew chassis 4 × 5 × 1-1/2 inches and painted it to match my Ten-Tec Corsair II transceiver. See **Figures 2** and **3** for foil pattern and component placement guide.* I used miniature coax on the bypass

PARTS LIST

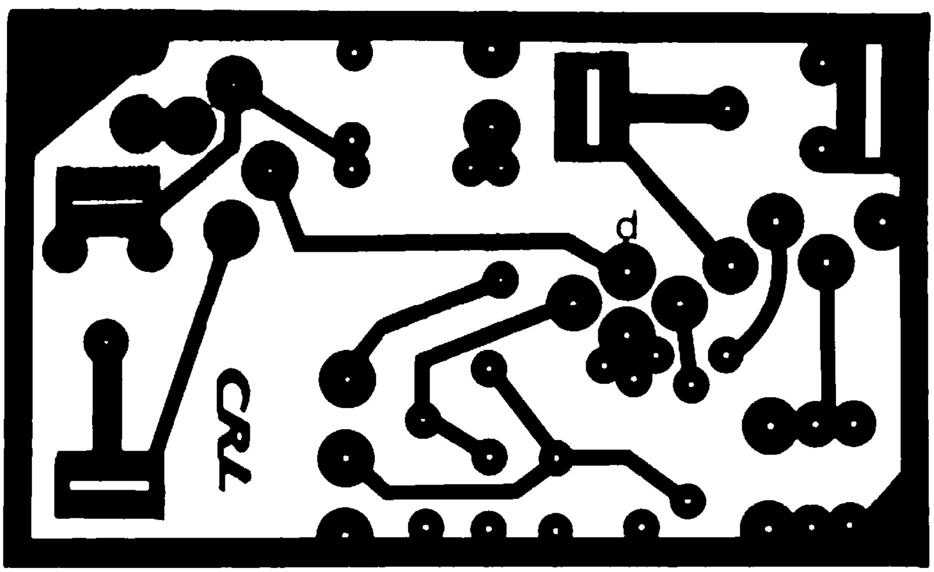
C1,C2	*Arco 429 compression trimmer*
CR1,CR2	*Silicon signal diodes or hot carrier for input protection (The 3SK88 already has built in protection, but this provides added safety.)*
L1,L2	*FT50-61 toroid core (Amidon, Micro-metals)* *L1, 22 turns tap at 11, 2* *L2, 22 turns tap at 11* *L3, 2 turns over L2*
Q1	*Nec 3SK88 or equivalent (ECG455)*
R1	*10-k pot with switch, Radio Shack 271-215A. All other resistors, 1/4-watt carbon composition; capacitors are 0.1-μF ceramic disc.*
S2	*DPDT miniature toggle switch for bypass (switch around)*
DS1	*LED to indicate power on RCA phono jack for power in*
Misc	*Two connectors (your choice) for input and output*

FIGURE 1



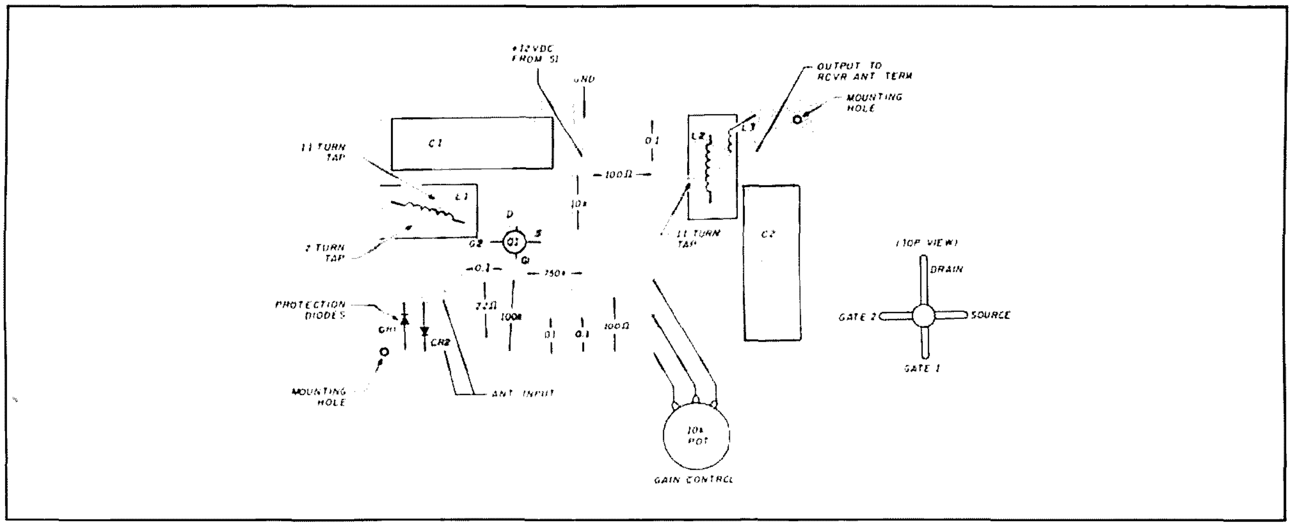
Schematic of the 160-meter pre-amp.

FIGURE 2



PC board foil pattern.

FIGURE 3



Component placement guide.

switch. Although the bypass isn't necessary, it's a feature I wouldn't leave out. The circuit board is mounted on two small threaded standoffs. Stick-on rubber feet and rub-on transfer decals give the project a "professional" appearance. The LED indicating power on is also nice, but not necessary.

Chuck Lewis, N8BYI, has kits available for $29.95 plus $2 shipping and handling. For more information, contact N8BYI at 4925 Vermont Lane, Fort Wayne, Indiana 46815; phone (219)749-2324.

Editor's Note: Those who want an 80-meter pre-amplifier should substitute either an FT50-63, or T50-3 core. Use the same number of windings as for the 160-meter pre-amp.

*Although a 7.5-k resistor is shown across the input tank circuit, it is not on the pc board artwork. This resistor was added to the circuit to broaden the bandwidth and provide a more constant 50-ohm match at the input. The circuit will work without the 7.5-k resistor with only slightly reduced bandwidth. Ed.

KD9SV Preamp User's Notes

Whether it's a bigger transmitting antenna, full legal power, or a way to improve my Beverage array, I'm always looking for an edge over my competition on 160 meters. Late last fall, KD9SV sent us a prototype 160-meter preamplifier to try out before he completed this article.

There are several important parameters that need to be examined when evaluating a preamp: is it prone to self-oscillation, can it handle both in and out-of-band strong signals, and does it induce any great amount of noise to the receiver?

One of the toughest tests you can give any piece of equipment is to use it during a major DX contest. I put KD9SV's preamp on line just before the CQWW® CW, and ARRL 160-meter contests and it performed without fault. The circuit is well designed and isn't prone to self-oscillation. It never "folded up" in the presence of strong adjacent in-band signals. The tuned front end effectively eliminates any problem with out-of-band stations. (KD9SV lives close to several AM broadcast stations and operates without problems.)

In casual operation after the contest, I did A-B comparisons with my other preamp to evaluate performance from a "known" standard. This design induces little additional noise in the circuit. The variable gain control is also a nice addition that lets you maximize gain without adding too much noise to the receiver.

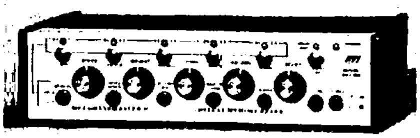
The acid test was trying to dig out weak signals. This preamp performed extremely well in all cases. Stations that were barely audible on the vertical or unamplified Beverages were perfectly Q-5 when I turned on the preamp. The only gripe I have about this preamp is that it's a single band unit. However, the overall improvement in operation is worth the minor inconvenience. I suspect I'll build another preamp for 80 meters sometime this summer.

de NX1G

Easy-To-Use MFJ-486 Grandmaster Memory Keyer

The MFJ-486 Grandmaster Memory Keyer™ gives you the power and versatility of a microprocessor memory keyer with knobs and buttons instead of a keypad. It comes with the new MFJ CW Word Processor™ that lets you change a message without having to rekey it. CW Word Processor Function keys let you move around within any message, insert, delete, and change your message. You also get the MFJ Custom-Speed™ control and a three-step built-in CW Course.

Other features include: 8000 characters of soft-partitioned memory in 10 memory banks, lithium battery backup, automatic incrementing serial numbering, message repeat and beaconing delay (1 second to 3 minutes), instant start from memory, manual or automatic work spacing, speaker, earphone/speaker jack, easy-to-use front panel controls for speed, weight, volume, tone and delay. There's also tune-up, A or B type iambic keying, Z-80 microprocessor, and more. Use 12 to 15 volts DC or 110 volts AC with MFJ-1312, 12.95.



A wired remote control, MFJ-77 for $19.95, lets you control memories and CW Word Processor function keys at your paddle.

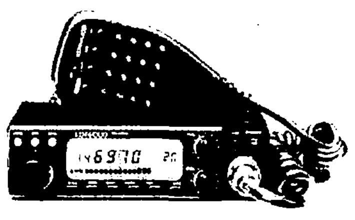
It comes with MFJ's new One Full Year No Matter What™ *Guarantee*.

For more information contact any MFJ dealer or MFJ Enterprises, Inc., P.O. Box 494, Mississippi State, Mississippi 39762, or call (601)323-5869, FAX, (601)323-6551, or order toll free at 800-647-1800.

Circle #303 on Reader Service Card.

New TM-231A Series VHF Transceivers

The new Kenwood TM-231A 2-meter FM transceiver has 20 memory channels, a DTMF microphone with control functions, a remote control head accessory, and a bright amber LCD display. It includes extended 2-meter frequency coverage (136 to 174 MHz receive) for MARS and CAP, and modifiable transmit range (permits required for modification information).



Models available for other bands include: TM-431A for 450 MHz, TM-531A for 1200 MHz, and coming soon the TM-331A for 220 MHz.

See your authorized Kenwood Amateur Radio dealer for more details or write: Kenwood USA Corporation, PO 22745, 2201 E. Dominguez Street, Long Beach, California, 90801-5745. Suggested retail prices: TM-231A: $459.95, TM-431A: $469.95, TM-531A: $569.95.

Circle #000 on Reader Service Card.

SG-9500 Signal Generator/Counter

The Elenco SG-9500 signal generator/counter combines a generator able to generate RF frequencies from 100 kHz to 150 MHz and a built-in frequency counter switchable to measure external frequencies up to 150 MHz in one unit.

The SG-9500A features include:

- Accuracy ±count ±1 digit
- RF output 100 mV RMS (up to 35 MHz)
- Output control 0 dB/20 dB switch with line adjustment control
- 1-kHz internal modulation
- Crystal oscillator HC-6/V holder
- Input voltage less than 50 mV
- Gate times selector 0.1 sec and 1 sec
- Input impedance HF 1 ohm VHF 50 ohms

The price is $349.95. For more information contact Elenco Electronics., 150 W. Carpenter Avenue, Wheeling, Illinois 60090.

Circle #304 on Reader Service Card.

SSTV and FAX System for Commodore Amiga

Advanced Electronic Applications, in agreement with Black Belt Systems, now offers the Commodore Amiga Video Terminal (AVT) "Master" system.

Developed by Ben Blish, N4EJI, and Dr. Anne Williams, N7LWZ, the AVT Master uses Amiga's graphics capabilities to transmit and receive high resolution facsimile and slow-scan television images. Received images can be printed on any Amiga printer or saved on a disk file. The AVT Master can manage your logbook, slow-scan TV (SSTV) system, packet bulletin board, and more.

The AVT mode features 400-Hz bandwidth. All video information is crystal-locked at both the transmitting and receiving stations at the start of each frame. The AVT Master can send high speed color images over the telphone lines to similarly equipped AVT Master stations. It also has telephone ring detect and auto answer.

The ATV Master system's suggested retail price is $299.95. For more details contact AEA, P.O. Box C-2160, Lynnwood, Washington 98036, Telephone (206)775-7373.

Circle #305 on Reader Service Card.

SCR7000X VHF/UHF Repeater

Spectrum Communications Corp. has released its new SCR7000X VHF/UHF repeater with a built-in microprocessor controller. All functions can be controlled remotely through either touch-tone or computer commands. Advanced panel controls include digital metering and a full compliment of system status LEDs. Also available are a number of state-of-the-art options to tailor the SCR7000X to your specific operating requirements. For more information, contact: Spectrum Communications, 1055 Germantown Pike, Norristown, Pennsylvania 19403.

Circle #308 on Reader Service Card.

OR-2300 Antenna Rotator

The new Orion OR-2300 antenna rotator uses a worm gear drive method and is rated at 35 square feet. The special compact design allows mounting in most popular crank-up and stacked towers. The control box has a large, easy-to-read direction indicator with variable speed.

Rugged mast clamps incorporating a self-centering guide accept mast diameters from 1-3/4 to 3-1/8". A flex mount clamping method self-corrects for misaligned masts and absorbs windload. Built-in thrust and double bronze bear-

(continued on page 84.)

THE BATTLE OF THE BEAMS PART 3

Ever since 1939, Dr. Plendl of the German Aeronautical Research Establishment entertained doubts about the effectiveness of X-Gerät in the face of strong jamming; accordingly, schemes for a new system were put in hand at that time. D. V. Pritchard Dip Ed, G4GVO, concludes this most interesting story.

By D. V. Pritchard, G4GVO, 55 Walker Dr., Leigh on Sea, Essex SS9 3QT, England

Ideally, such a system would have only one director beam for the guidance of the bomber, and another for a range measurement system which would enable ground control to drop the bombs accurately. Clearly improved accuracy would be needed, and it was possible that owing to the nature of the system the number of aircraft on the beam at any one time would be necessarily low.

Early experiments

Since the only aircraft receiver available was the FuG 17 (42 to 48 MHz), a multibeam beacon was designed for it by a Dr. Herzog of the Gotz Company and given the code name *Wotan 2*. A system similar to X-Gerät was also built which used the *Bertha 1/-2* television transmitter, with similar pulsing and modulation having a dot/dash ratio of 1:7 modulated at 2000 Hz. Plendl's analyzer was also employed; this system was envisaged as the director beam for the aircraft's flight path.

For range measurement, another special "dash system" was developed at Rechlin. A transmitter tunable between 42 and 48 MHz was modulated for 10 seconds at 300 Hz; its signal was received in the aircraft on a later mark of Herzog's receiver — now the FuG 17 E and on the German production line. Its output was fed through a tone filter and the resulting note modulated an airborne transmitter, which returned the signal to the ground on another frequency in the 42 to 48-MHz range. There the returned modulation note was compared with the original one sent from the ground and the phase difference, after deduction of the time lag in the aircraft's equipment, gave a direct measure of the range between the ground transmitter and the aircraft.

Different ideas

In fact several systems were tried for the early Y-System, but the one chiefly employed was the "Y-Range Measuring System Mechanical" developed by Dr. H. J. Schmidtmann at Rechlin and Dr. Jenns of Siemens (see **Figure 1**). Two tone frequencies of 300 Hz (corresponding to 500 km, the "coarse measuring range") and 3000 Hz (equaling 50 km, the "fine tuning range") were transmitted. Rectifiers loosely coupled to the transmitting antennas fed both frequencies via separate filters and phase converters to two small c.r.t.s, which were also fed the filtered frequencies from the receiver tuned to the aircraft's return signal. Tuning the phase converter resulted in diagonal strokes appearing on the screens which served as null-point indicators; range was read from a scale marked in kilometers.

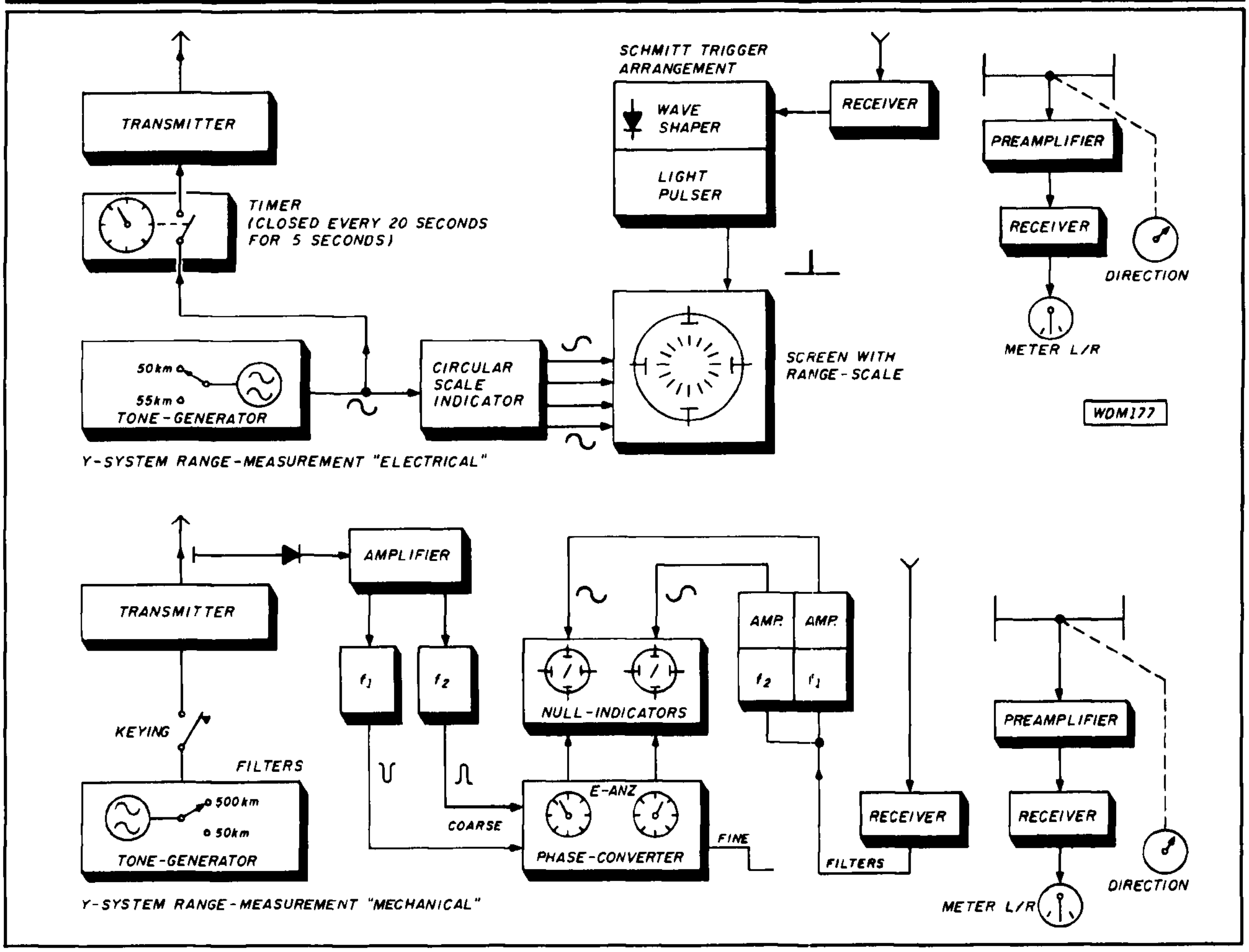
Siemens also produced a range measurement known as the *Electrical Notebook*, which recorded the ultimate range of five simultaneously measured aircraft. This incorporated a fine-measuring system devised by a Dr. Bekker that used a larger c.r.t. with a circular range scale showing a range from 0 to 20 km. A transmitted tone of 7500 Hz generated a "dark pulse" circular time zone calibrated against a further circular "bright zone." The phase-converted voltage from the receiver was then transformed into a pulse which the electron beam converted into light points, so that a change in range could be observed directly. This system was somewhat unreliable in that a 5-km variation in range was sometimes observed, but nevertheless it was of some help when enemy jamming was strong.

Later, Dr. Bekker introduced another device known as the "Y-System Measuring Electrical" which was produced by the Graetz Company. A modulation note of 300 Hz corresponded to 50 km, but it could also be used for an indication at, say, 20 km. Switching to a frequency 10 percent higher extended the range to 32 km, and so on. Little more, unfortunately, is known about this method.

First trials

These systems were, however, only useful for random location at first. Only an all-round representation of an aircraft was given. For example, the aircraft flew to a given point by standard navigational methods and its range was then measured by these various electronic systems. Its approach to the point was ascertained by coupling the system to an ultra-shortwave Adcock direction finder, code named *Heinrich*. Variants of the earlier X-Gerät system were often incorporated wherein a director beam was used. But

FIGURE 1



Block diagram of the Y-system range-measurement systems, electrical and mechanical.

the place where the old cross beams would have been employed, instead of the X-Uhr combined clock/calculator, would indicate the precise timing according to range measurement from the ground. On approaching the bomb release point the X-Uhr received a 9-second Morse signal. The bombs were released on the last dot.

Final form

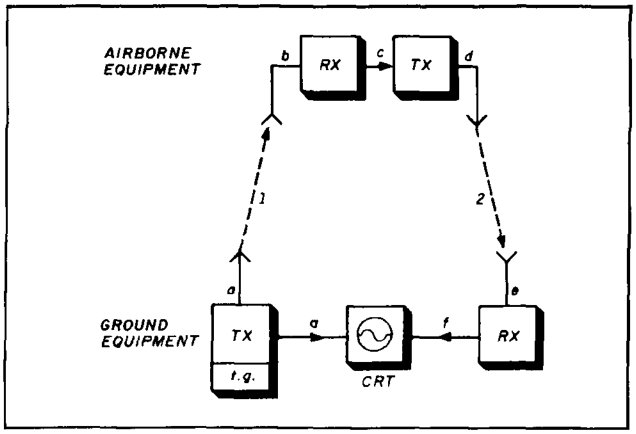
In 1940, under the direction of Dr. Plendl, a development was devised from this method by Dr. Herzog. This new system retained the code name *Wotan 2*. Its full title was the "Y-Double-Beam Beacon System" and it included parts of the multibeam system already described (see **Figures 2** and **3**).

Although the same rotating installation with transmitter and operating cabin was used, new antennas were introduced with seven parallel dipoles and reflectors, which generated a long club-shaped lobe with smaller side lobes. At a half wavelength in front of these were two further dipoles spaced at a wavelength apart which, on an opposite phase, produced a "washed out" cardioid pattern. Thus two sets of beams were sent out — one for the flight path to the target, and the other for the aircraft's return. (Refer to Figure 4.)

Keying the system was originally effected by mercury switches or vacuum relays, but as they gave rise to key clicks, they were replaced by the so-called "capacitive mill" designed by a Dr. Escherish. This was a motor-driven differential capacitor which used a light bulb to take the transmitter load between the pauses in transmission. The long lobed directional antennas were keyed at 176 pulses per minute followed by the cardioid-shaped dipoles. This resulted in a slower dot/dash pulse with much shorter gaps at a ratio of 8.8:1, and was acoustically more acceptable.

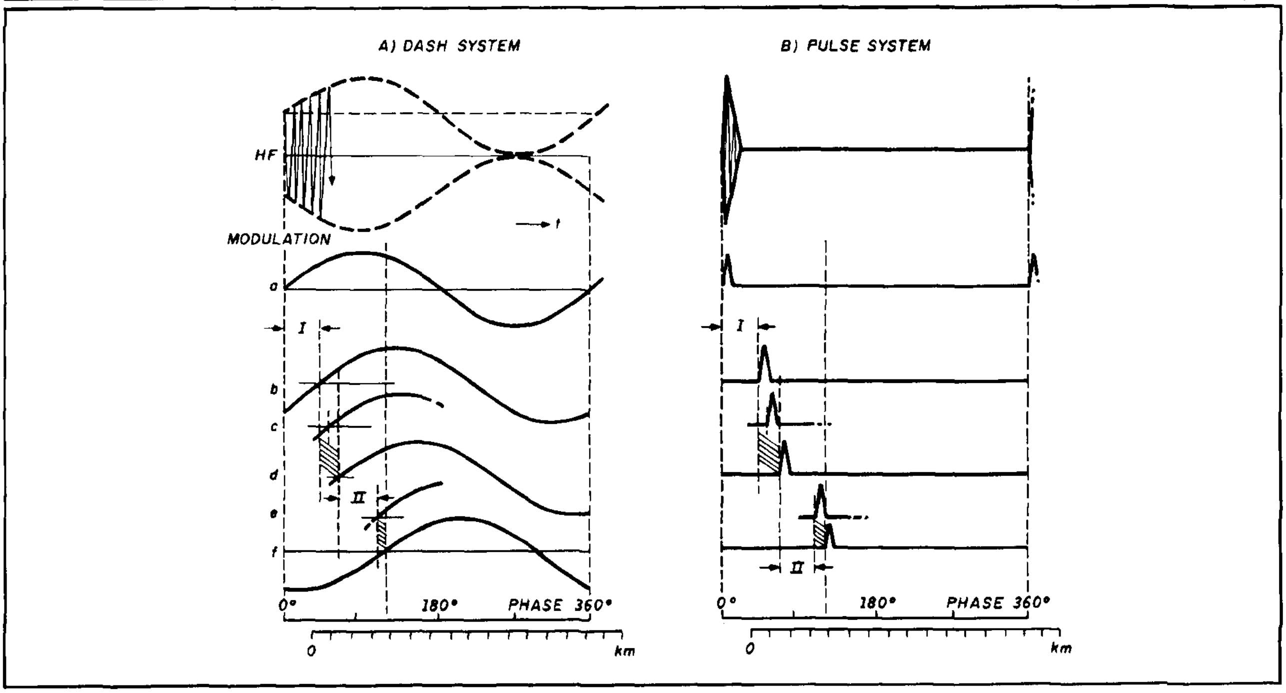
In addition, a new receiver based upon Herzog's FuG 17 E was developed by Dr. H. Donn and Dr. W. Hepper; it was designated the FuG 28a and manufactured by the Heliowatt Company. This was combined into one unit with Plendl's improved AW 28 analyzer. The latter contained a motor driving a cam making 180 contacts per minute, which conducted the receiver output to two series-connected capacitors. Their differential voltages then biased the grids of two valves so that one was bridge switched. A balance existed if the field strength of the two pulses from either transmitter was the same; that is, if the aircraft was found on one of the two beams. Variation to left or right gave opposing bridge currents, with corresponding responses on the indicating meters.

FIGURE 2



General layout of the Y-system. (1) Outward beam. (2) Return beam. t.g.- tone generator, TX—transmitter. RX - receiver.

FIGURE 3



Graphs of range, modulation, and timing of the Y-system. The running time inside the equipment is shown on the shadowed parts of the graphs. The range scale is therefore displaced by this value on the right-hand graph (B).

The gap between transmissions in each case caused a magnetic coupling between the motor and the switch to drop, and to be reinstated only when the next cycle of transmissions commenced. In this way a positive synchronization between the ground station and the aircraft was established. To position himself on the correct beam, the pilot switched on his equipment — which also incorporated a sensitive, heavy-duty relay with an extra winding. The relay operated according to course variations by switching over the polarity for left and right directions. Thus the motor would be in the correct rotation sense when switched on, until a potentiometer connected between the motor and the additional winding on the relay delivered sufficient voltage to release the relay.

The Y-System could probably have been the most effective (if not dangerous) system of all the German beams had it not been for one small item the Germans, in spite of their customary thoroughness, had somehow overlooked.

Norse mythology — the giveaway

As early as June 1940, when Dr. R. V. Jones had final proof of the existence of Knickebein, he received an Enigma decode from Bletchley Park. *It is proposed to set up Knickebein and Wotan installations near Cherbourg and Brest.*

Wotan was certainly something new, but what did it mean? He knew that Wotan was the greatest of the German gods, but was there anything unusual about him? What attributes did he possess that moved the Germans to use his name as a code word?

Jones phoned his friend Frederick "Bimbo" Norman, Professor of German at King's College, London, then one of the cryptographers at Bletchley Park. "Bimbo" was renowned for his lightning-fast mind and at once gave proof of it.

"Yes, Wotan was the chief German god. Wait a moment...he had only one eye. One eye, one beam! Can you think of a system that would use only one beam?"

Dr. Jones could, in principle; but it was not until the end of 1940, when X-Gerät was finally mastered, that he and his assistant Dr. F. C. Frank suspected that another German beam system might be making its appearance. Could this be the *Wotan* they were looking for? The new system

seemed to involve a director beam plus a means for ranging. Jones's suspicions were aroused when on October 6 an Enigma transmission to what appeared to be a station called "Wotan 2" northwest of Cherbourg read, *Target no. 1 for "Y" coordinates 50°41'49.2" north, 2°14'21.2" west.* Study of a map revealed these to be the coordinates of an army depot at Bovington in Dorset. They showed a great difference from the X-Gerät system in which a number of beam directions were always sent out, each station having to set its beam in the required direction. With this new method, however, the position of the target was given to a single station, which suggested that the station had the entire means of directing the bomber to its target. This seemed to be confirmed when Bovington was attacked a few days later by two aircraft with results which, though somewhat inaccurate in direction, were good as regards the range.

Frequencies and cyphers

Signals Intelligence and our monitoring services soon began to report the existence of beams on frequencies between 40 and 50 MHz which had very different characteristics from Knickebein and X-Gerät. Instead of the left and right transmissions being modulated with dots and dashes, the emissions were of equal duration — except for a short pause in transmission when one signal, for example the left, came directly after the pause and the other signal followed in a sequence thus: pause — left, right, pause — left, and so on.

Dr. Robert Cockburn and his assistants at the Telecommunications Research Establishment put the signal on an oscilloscope, and immediately observed its principle. The beam emitted three directional transmissions per second and seemed to have been designed to operate a beam flying indicator in the aircraft. As things turned out, more surprising developments were to be revealed.

Jones discovered that the aircraft using the new system were not from K.Gr.100 but from the Third Group of KG 26. He also learned that the scientist who had developed the system was none other than Dr. Plendl who had devised X-Gerät. Plendl was the German equivalent of T. L. Eckersley, our leading radio propagation expert. When Jones asked Eckersley what he thought of Plendl he replied, "He's not much good, he bases his theory on experiment!" *(Amateurs please note!)*

On January 19, 1941, an aircraft of KG 26 was shot down and, though it was badly damaged, it could be seen that it carried equipment similar, though not identical, to X-Gerät. But of greater significance was the radio operator's charred notebook:

Loge	*244*	*142*	*10*
Schmalstigel	*454*	*149*	*11*
Bruder	*372*	*120*	*11*
Suden	*272*	*117*	*11*
Bild	*405*	*137*	*11*

Rückflug

Knowing that KG 26's base was at Poix, southwest of Amiens, and that "Loge" was the German code name for London, Jones and Charles Frank were able to make the following interpretation:

Objective	*Distance to Poix*	*Rhumb bearing to Poix*	*Magnetic variation*
London	*244 km*	*142°*	*10°*
Sheffield	*454 km*	*149°*	*11°*
Bristol	*372 km*	*120°*	*11°*
Southampton	*272 km*	*117°*	*11°*
Birmingham	*405 km*	*137°*	*11°*

Homeward flight

The second table in the notebook gave:

Hinflug	
294	*10*
318	*11*
283	*11*
274	*11*
302	*11*

By assuming that these entries referred to the same cities as those in the first table, and that they were bearings, the intersection point appeared to be at Cassel in north France, which gave them:

Outward flight

Objective	*Approach bearing from Cassel*	*Magnetic variation*
London	*294°*	*10°*
Sheffield	*318°*	*11°*
Bristol	*283°*	*11°*
Southampton	*274°*	*11°*
Birmingham	*302°*	*11°*

Jones could therefore deduce that:
(a) the aircraft approached its target from the direction of Cassel; (b) the pilot was not concerned with distance calculations, which would be consistent with the distance being determined by a distant ground station; and (c) after the plane had reached its target, the pilot intended to return directly to an airfield near Poix. And since he was navigating on his own, he needed to know the distance from the target back to Poix — as well as the direction.

A third table in the notebook contained the frequencies for both the beam itself and the ranging system. Typically, the station radiated a sinusoidally modulated signal to the aircraft on 42.5 MHz and its modulated note was then detected, amplified, and used to modulate a transmitter in the aircraft, which sent a signal on 46.9 MHz back to the ground station. The distance of the aircraft was determined by the delay in the return signal. As we know, an analyzer was used.

The delicious leg pull!

From a security viewpoint it is remarkable that the Germans failed to ensure that notebooks and tables giving important information were not taken aboard aircraft. It would have been a simple matter to memorize these things for a single operation. On the other hand, it could be said that the Germans were completely unaware that we had broken their Enigma signal system, which gave away so much more vital information. At all events, these matters added up to British intelligence being able to glean much information which the enemy confidently believed to be secure.

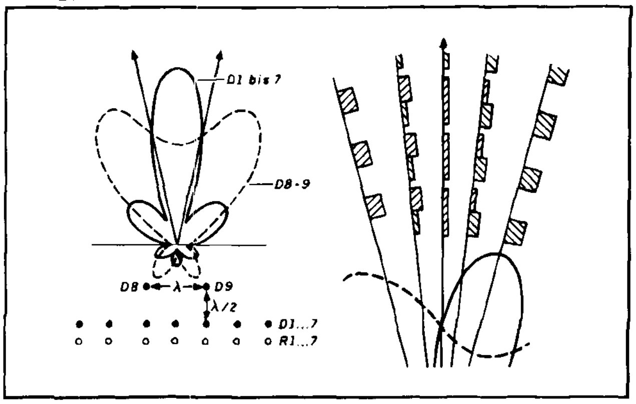
Dr. Jones immediately spotted a "delicious" method of

upsetting the Y-System, as shown in **Figure 5**. (Doubtless his prowess in practical joking came to his assistance here. After all, if disguised as a telephone engineer he had been able to persuade an Oxford physicist to plunge a telephone into a bucket of water, finding a way to bamboozle the enemy was likely to come quite readily to mind.) We in England could receive the 46.9-MHz signal from enemy aircraft even better than their ground station could, and so we could *re-radiate the already re-radiated signal back to the aircraft on 42.5 MHz, the frequency used by the ground station.* As Dr. Jones pointed out, *"This would therefore be fed into the aircraft receiver, along with the signal coming in from the ground station, and in turn be fed back to the ground station again. The effect would be rather like that which occurs in public address systems where the noise from the loudspeakers impinges on the original microphone, and is therefore picked up and relayed back to the speakers again. It would appear to the ground station that the aircraft was at a false distance, because the returning waves would have traveled round an extra loop between the aircraft and our own station before getting back to their original base; and if we used a powerful transmitter ourselves, the whole system would ring just as a public address system squeals if the gain of the amplifier is made too high."*

The BBC television transmitter at Alexandra Palace was just right for the task because it operated in the right frequency band. Dr. Cockburn immediately requisitioned it for the purpose and it transpired that this countermeasure, code named *Domino*, was first put to use the very night that KG 26 took over from K.Gr.100 — because we had now successfully jammed X-Gerät.

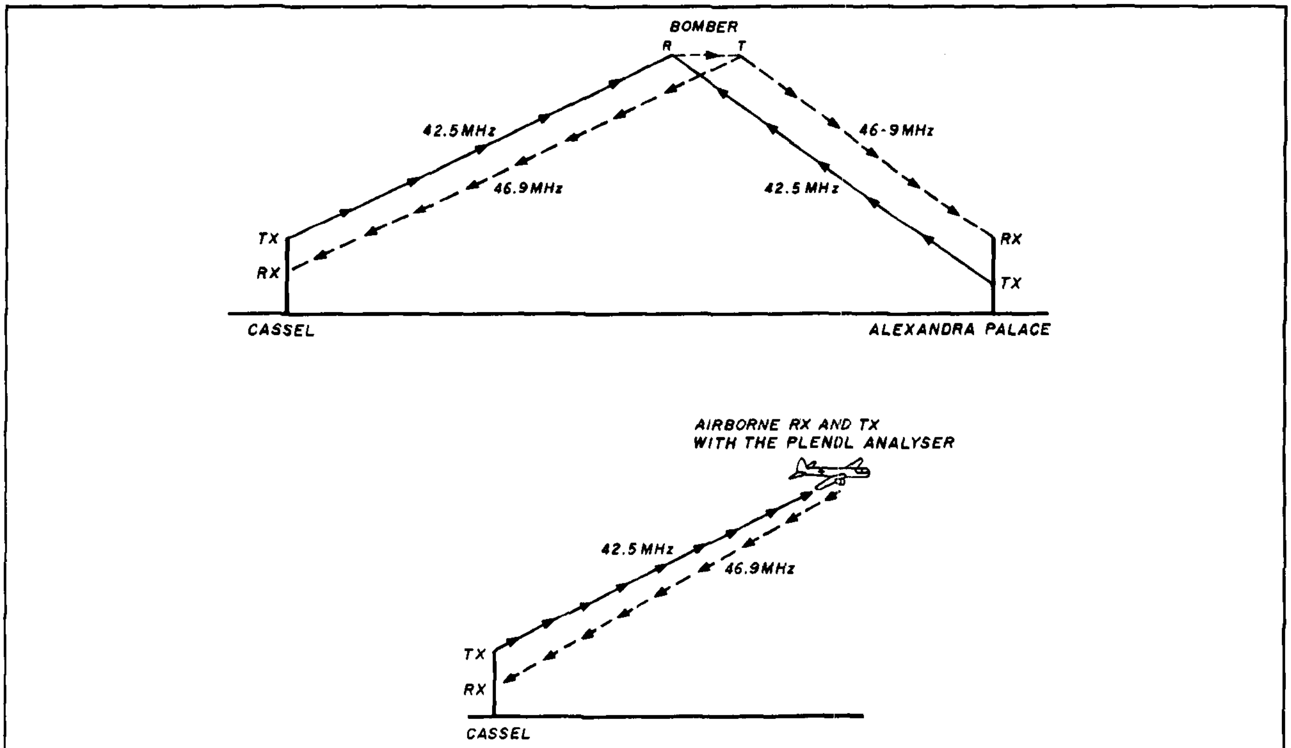
Jones advised that for the first few nights only a minimum of power should be used, just enough to inject a small signal into the Y-System to give the Germans a false range without arousing their suspicions (a process of "acclimatization" by slow change). The first results were not only successful, but afforded a source of innocent merriment. One aircraft became involved in an acrimonious exchange with the ground station, who suggested he must have a loose wire in his receiver and that he should abandon the attack

FIGURE 4



Official German diagrams of antenna patterns for (left) return path and (right) directional pulsed beam.

FIGURE 5



The method of interfering with the Y-beam system and the ranging principle of the Y-system.

for that night. Over the following nights Alexandra Palace gradually increased its power and the Germans woke up to the fact that we were now successfully jamming the system, whereupon they abandoned it.

Dr. Jones's original aims were that, since he was not entirely sure for how long the Germans had successfully used the system, he should break their confidence by making them think that we had been interfering with it in a way that had remained undetected for considerable time. This policy reaped further (and at times hilarious) bonuses because once the Germans suspected we were interfering with the system other alarms entered their heads. *"Since the aircraft had to be instructed by the ground station when to release its bombs, it had to be monitored all the time during its bombing run, and the ground station could handle only one aircraft at a time. The aircraft would therefore fly to a convenient area from which it could be ordered onto the beam by the ground station, and so commence its bombing run. In principle, all we needed to do was transmit false orders to the aircraft. In fact we did not do this, but it seemed such an easy countermeasure that the German crews thought we might, and they therefore began to be suspicious about the instructions they received."*

Substance was added to this later when an aircraft was ordered by the ground station to steer due west (possibly because it was east of the beam) to bring it onto the start of its bombing run. Failing to hear further ground station orders, the aircraft flew a considerable distance west, then returned to base to complain that the British had given false orders. On other occasions, when the power of Alexandra Palace had been increased, aircraft became confused and were ordered back to their bases after being told, again, that a wire was probably loose somewhere in the equipment. *"What with our real countermeasures and those imagined by air crews, Y-operations became a fiasco and the system was withdrawn; we had restored our moral ascendency for the rest of the winter"*

Only later did Dr. Jones learn that the Y-System was really *Wotan 2*, and X-Gerät was *Wotan 1*. *"And so, while Wotan may have had one eye for 'Y,' he could not have crossed eyes for 'X'..."* In fact the Y-System was nicknamed "Benito" because Mussolini was considered to be the one-eyed end of the Axis!

So ends the battle of the beams. I hope that some interest may have been aroused in you to study this aspect of scientific warfare further, and to live again those momentous days of the 1940s in the company of such distinguished (if then secret) servants who unraveled the enemy beam systems.

But to one man, above all, must go the highest recognition: R. V. Jones, the young scientist who defied the experts, confounded officialdom, and quietly saved the country from a terrible disaster — yet inexplicably, is still denied the knighthood he so richly deserves. The man who, to repeat Churchill's words, *"broke the bloody beams."*

Acknowledgments

I am grateful to Professor R. V. Jones, Emeritus Professor in the Department of Natural Philosophy, University of Aberdeen, for his kind help and advice, and also for his permission to use extracts from his book *Most Secret War*, published by Hamish Hamilton. My thanks must also go to AEG (formerly Telefunken) for their permission to use extracts from *Die deutschen Funklenkverfahren bis 1945*, and especially to Dr. Colin Hamilton, manager of the Airborne Early Warning Department, for his kind assistance and advice. I am also grateful for the help received from some old and respected opponents, notably Herr Fritz Trenkle, author of *Die deutschen Funk-Navigations und Funk-Führungsverfahren bis 1945*; Dr. Rudolph Kühnhold, designer of the *Freya* and *Seetakt* radars; the late Professor Dr. Wilhelm T. Runge, designer of the *Mannheim, Darmstadt, Würzburg* and *Lichtenstein* series of radars, who was able to give valuable help regarding Telefunken's work in the field of beam systems; and Dr. Herbert Kummritz, Dr. B. Röde and Dr. Gotthardt Müller.

Further reading

Most Secret War by R. V. Jones. Published by Hamish Hamilton.
The Bruneval Raid by George Millar. Published by The Bodley Head.
The Ultra Secret by F. W. Winterbotham. Published by Nicolson.
The Rise of the Boffins by Clark.
Instruments of Darkness by Alfred Price.

For our German speaking readers:
Die deutschen Funk-Navigations und Funk-Führungsverfahren bis 1945 by Fritz Trenkle. Published by Motorbuch Verlag.

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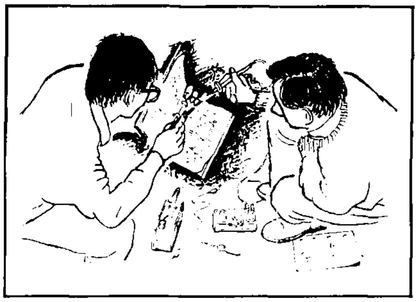
Ham Notebook



A Remote Control Switching System

Because I had up to four HF antennas in use, I decided to control each antenna remotely by feeding them to a relay box, using a single coaxial line to the operating position.

The relay box contains two DPDT relays and five SO239 sockets. At the operating position there's a box with a three-pole four-position wafer switch and four LEDs to indicate the antenna in use. A two-conductor cable, in conjunction with the shielded outer braid of the main coax, feeds 13.8 volts, taken from the transceiver power supply to the relays. The details are shown in **Figure** 1, the circuit diagram.

Operation details

Switch position 1 — both relays are passive connecting antenna A.

Switch position 2 — relay no. 1 energized connecting antenna B.

Switch position 3 — relay no. 2 energized connecting antenna C.

Switch position 4 — both relays energized connecting antenna D.

The relays are Archer catalog no. 275-2188. The system has been in use for over 12 months on frequencies from 28 to 3.7 MHz with entirely satisfactory results.

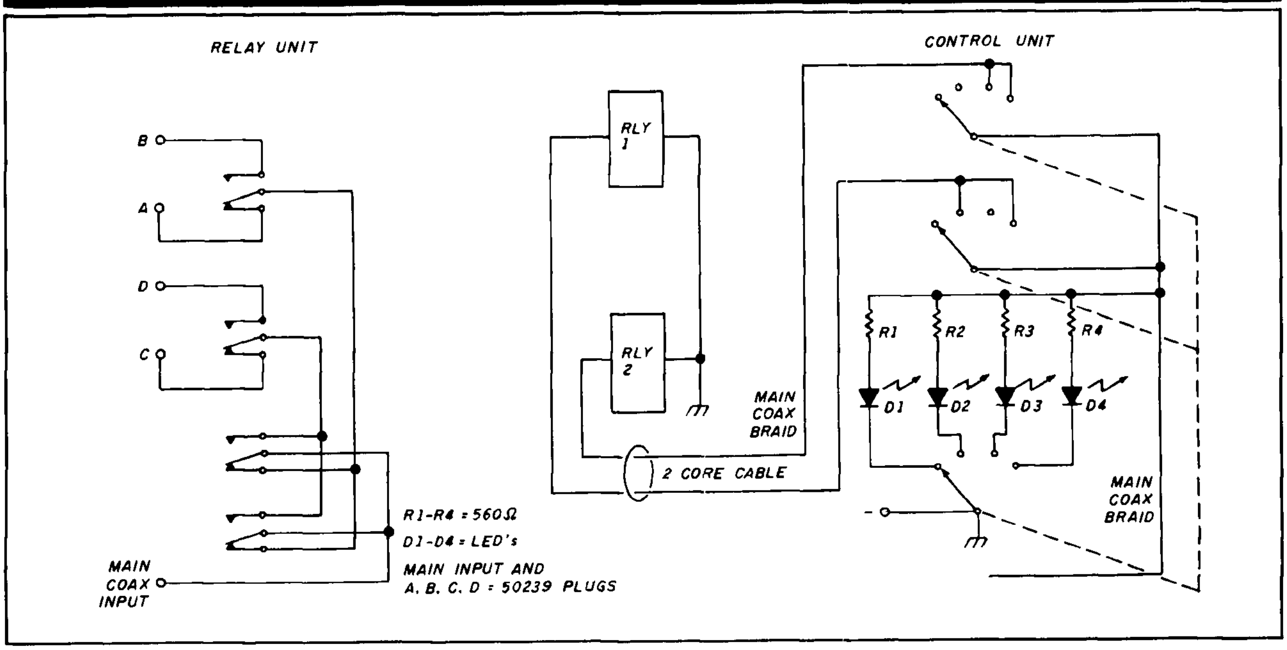
Bill Duke, VK2WD

*Reprinted with permission from *Amateur Radio*, Wireless Institute of Australia, September 1988, page 26.

Transistor Lead Identification with a DVM

You don't always have a drawing showing which leads of a junction transistor are which when you're connecting the transistor in a circuit. But you can tell which lead is the emitter, which is the base, and which is the collector, and also identify the transistor as a PNP or an NPN type by using the ohmmeter of a digital voltmeter. First turn the ohmmeter to a scale that will forward bias a diode (these scales often have a diode symbol beside them), and leave it on this scale for all of the following measurements. Connect the ohmmeter to all possible pairs of the transistor's leads, using both polarities. If the transistor is good, only two of the six combinations possible will show conduction. The two leads having the higher indicated resistance on the ohmmeter are the base and the emitter; the remaining lead is the collector. Only one of these two leads will show resistance when the collector is

FIGURE 1



Circuit diagram for remote control antenna switching system.

one of the leads connected to the ohmmeter. This lead is the base. Since you've identified both the base and collector leads, the remaining lead must be the emitter.

To identify the transistor as NPN (the most common) or PNP, connect the ohmmeter to two of the leads so conduction is indicated. If the positive ohmmeter lead is connected to the base, the transistor is NPN — otherwise, it's PNP. This method works because the emitter (which has the same type of doping as the collector) is always doped more heavily than the collector. When a given current is forced through the emitter-base junction, a higher voltage is required to overcome the greater built-in voltage of the space charge region than is needed for the more lightly doped collector-base junction. All DVM ohmmeters work by forcing a current through the leads and indicating the voltage that results (calibrated as a resistance). A given current amplitude "reads" as a higher resistance when forced through the emitter-base junction than it does when it's forced through the collector-base junction.

Bob Henderson, KØGSS

THE PV-4
ON YOUR COMMODORE

Designing high performance Yagi antennas

By Alan Hoffmaster, WA3EKL, 929 Andrews Road, Glen Burnie, Maryland 21061

The following program is an upgraded version of one published in *Ham Radio* in June 1985.[1] The program lets you duplicate the performance characteristics of the PV-4 accurately without having to build a PV-4 clone.

PV-4 background

Jim Lawson, W2PV, never published the PV-4.* It was a custom design for a number of New England area contesters, who make good use of it today — along with W3LPL and myself. This particular array defied Jim's original findings of equal spacing and directors all of equal length. It also makes use of an odd boom length, 0.57 wavelength. The reflector, driven element, and first director are all bunched down at one end of the boom and the second director is the other end of the boom, making the array mechanically unbalanced at the center. However its performance characteristics are exceptionally good. The Yagi maintains a high gain (10 dB) over the whole band and at least 20-dB front-to-back ratio, with a very high peak (40 dB) at the central design frequency. The central design frequency should be chosen in the middle of the phone band, because the performance characteristics tend to deteriorate rapidly as frequency is increased. A beam designed this way will still perform very well in the CW portion of the band; however, the reverse is not true.

With the aid of a rather large computer, Lawson explored numerous combinations of Yagi element spacings and resonant lengths. He chose a combination that yielded a high gain and front-to-back ratio over a 3-percent bandwidth, which covers most Amateur bands. His original designs[2] used equal element spacing and a 5.26×10^{-4} wavelength average diameter. Using these criteria, he established a chart[2] of resonant element lengths of constant diameter for two, three, four, five, and six-element Yagis. *I* call the chart "The Magic Numbers."

Design parameters

Jim left us with a set of mathematical formulas as important tools to design high performance antennas.

*Jim Lawson, W2PV, is known for his many articles on Yagi antennas published in *Ham Radio*. He is now a silent key. Ed.

Tool A
The ability to determine accurately the magic numbers for any average diameter chosen.
Tool B
The ability to determine accurately the resonant electrical length of a tapered element at any frequency.
Tool C
The ability to scale, or shift, the antenna resonant frequency to anyplace in the desired band and have the scaled model perform in exactly the same way as the original.

Because I've received many queries about my original program (and this one is very similar), I'll explain it in more detail. Those of you who've already typed in the original program should have no trouble modifying it — even if your computer isn't a Commodore.

Program notes

As the PV-4 began to appear, none of the articles gave the magic numbers and the average diameter associated with them, until K1GQ published them in 1986.[3] Before K1GQ's article appeared, I tried to extrapolate the magic numbers from the various designs in the literature, but couldn't get consistent accuracy. My challenge was to convert K1GQ's magic numbers, based on a 0.001 wavelength average diameter, to 5.26×10^{-4} wavelength average diameter, which is what my programs run on. The program does this for you. After it computes the average diameter of the element you've input (lines 720 through 740), it checks to see if the average diameter is 0.875, which corresponds to a 5.26×10^{-4} wavelength on line 1450. If the average diameter isn't 0.875, then lines 1430 to 1530 calculate a new set of magic numbers for the average diameter of the input element. To prove that the new magic numbers are correct, I wrote the following program from lines 1480 through 1560 of the main program.

Proof program

```
70 DIM A(4), B(4)
80 FOR H=0 TO 3
90 A(H)=0:B(H)=0
100 NEXT H
110 A(0)=0.49528: A(1)=0.48028: A(2)=0.44811:
A(3)=0.44811
120 RA=0.000526
130 RB=0.001
140 KA=1/RA
150 KB=1/RB
160 FOR J=0 TO 3
170 F1=(1-((10.7575*(LOG(KA)/LOG(10)))-8^-1)/(2*A(J))
180 XX=((215.15*(LOG(KA)/LOG(10)))-160)*((1/F1)-F1)
190 AA=XX/((215.15*(LOG(KB)/LOG(10)))-160)
200 F2=(-AA+((AA^2)+4)^0.5)/2
210 B(J)=(1-((10.7575*(LOG(KB)/LOG(10)))-8)^-1)/(2*F2)
220 NEXT J
230 ? B(0)
```

```
240 ? B(1)
250 ? B(2)
260 ? B(3)
270 END
```

If you plug in the numbers from Jim's chart[2] on line 110, and use a 0.001 or 0.008-average diameter on line 130, you'll get an accurate set of all of his figures. When you insert K1GQ's magic numbers on line 110, 0.001 average diameter on line 120, and 5.26 × 10^{-4} on line 130, the preceding program calculates a new set of magic numbers based on a 5.26 ×10^{-4} average diameter. You'll find it on line 1400 of the main program. I used the same procedure to prove the rest of the program. The original program was written on my Atari computer. It took my wife (N3DPB, an excellent program debugger) and me four hours of debugging this one little subroutine before we could consistently reproduce Jim's figures. After that, it took another three hours on the phone with WA3HQX, who converted the subroutine to the Commodore format.

Program explanation

Lines 100 to 400 are a brief history and list of recommendations. Lines 400 through 780 store the user input information in the various arrays and variables with a subroutine, and lines 1750 to 1810 print the information to the screen. Line 750 takes you to a subroutine (lines 1360 through 1640) which calculates the normalized element half lengths for whatever average diameter element you input, and then stores the data in other variables. Next, in line 760, you gosub again to lines 1650 to 1720, which print the normalized lengths to the screen. Lines 790 through 1050 calculate the actual electrical resonant element half length (called the "total equivalent length") per the data you've input, and prints it to the screen. Program line 1050 asks if you want to change a segment length. The object is to adjust your segment lengths until the total equivalent length is equal, or very close to, the "normalized length" for the element you're working on. Lines 1050 to 1140 let you do this. Finally, lines 1150 through 1350 print all of the data to the screen.*

Avoiding stumbling blocks

This program, as is, will run on an Atari computer With a few modifications it will probably run on most others. The only difference between the Atari and Commodore programs is the way in which each computer calculates the common logarithm. This was a major hangup for WA3HQX and me in trying to get from Atari to Commodore. For instance, if you say LOG5 in Commodore language, the computer takes the natural log of 5 (or log to the base e of 5). This program and Jim's formulas use the common log or log to the base 10. To convert from the natural log to the common log in Commodore language, you must divide the natural log by the natural log of 10. For example: LOG5/LOG10 = common log of 5 in Commodore language. In Atari language, you simply say CLOG5 to get the common log of 5. Check your computer's BASIC language book to see how it calculates the common log, and make the appropriate changes to lines 910, 1510, 1520, 1530, and 1550.

*WA3EKL's program is available from *Ham Radio* upon receipt of a self-addressed, large, stamped envelope. Ed.

Hints for Atari users

For Atari users who want to make the program run a little faster, and also make it a little easier to type in, change the aforementioned lines to the following:

```
910 M=((43.03*CLOG(K2))-32)/((43.03*CLOG(K1))-32)
1510 F1=(1-((10.7575*CLOG(KA))-8∧-1/(2*A(J))
1520 XX=((215.15*CLOG(KA))-160)*((1/F1)-F1)
1530 AA=XX/((215.15*CLOG(KB))-160)
1550 B(J)=(1-((10.7575*CLOG(KB))-8)∧-1)/(2*F2)
```

I hope this explanation helps you understand how the program runs. The rest of the program is straightforward, simple, and basic. All the formulas can be found in Jim Lawson's original articles.

It was Jim's desire that the Amateur community build, evaluate, and report to each other how his monoband Yagis performed. I have built Jim's three-element design on a 0.3 wavelength, and his four-element design on a 0.75-wavelength boom. W3LPL has built Jim's six-element design on a 0.75-wavelength boom. Both W3LPL and I have built Jim's specialized four-element design on a 0.57-wavelength boom.

Results

I built the three-element version for 10, 15, and 20 meters. They work unbelievably well. I could hold my own very easily in a contest with the big guns. W3LPL's six-element versions on a 0.75-wavelength boom played extremely well, according to all the operators who worked his station during the DX contests. I also built a four-element, 10-meter version on a 0.75-wavelength boom. No matter what I did to it, including placing it on different towers at different heights (56 and 67 feet) and retuning the elements, it wouldn't play. The gain seemed very low and the front-to-back ratio was bad. I recommend that you don't build the four-element version on a 0.75-wavelength boom. However, the four-element version you can design on a 0.57-wavelength boom using this program is an entirely different story. During the summer of 1987, W3LPL built a four-element, 20-meter version. Even though my three-element, 10 and 15-meter antennas worked great, I changed them to four-element versions with this program.

After completing the 1987-88 contest season under the call K3ZZ, I could honestly say that the results were indescribable. To quote some of the operators at the 10 and 15-meter positions, "It was like shooting a cannon at the DX." While I still had the three-element versions up, we were able to achieve third place in one of the ARRL DX phone contests, multi-multi category. That's quite an achievement; we had just two towers in an area 63 feet wide and 140 feet deep, and our highest antenna was a three-element, 20-meter monobander at 76 feet!

I'm a believer in Jim Lawson's designs, and so are the contesters who operate my station under the call K3ZZ. When you hear WA3EKL or K3ZZ during a contest, you'll know what we're using. I hope this article encourages you to build this superior four-element monoband Yagi. Good luck and good DX! hr

REFERENCES

1. Alan Hoffmaster, WA3EKL, "Designing Yagis with the Commodore 64," *Ham Radio*, June 1985, page 59.
2. James L. Lawson, W2PV, "Yagi Antennas: Practical Designs," *Ham Radio*, December 1980.
3. Bill Myers, K1GQ, "The W2PV Four-Element Yagi," *QST*, October 1986, page 15.

DIGI-KEYER

An easy-to-build TTL design

By Ronald D. King, AB4DP, 569 Croley Drive, Nashville, Tennessee 37209

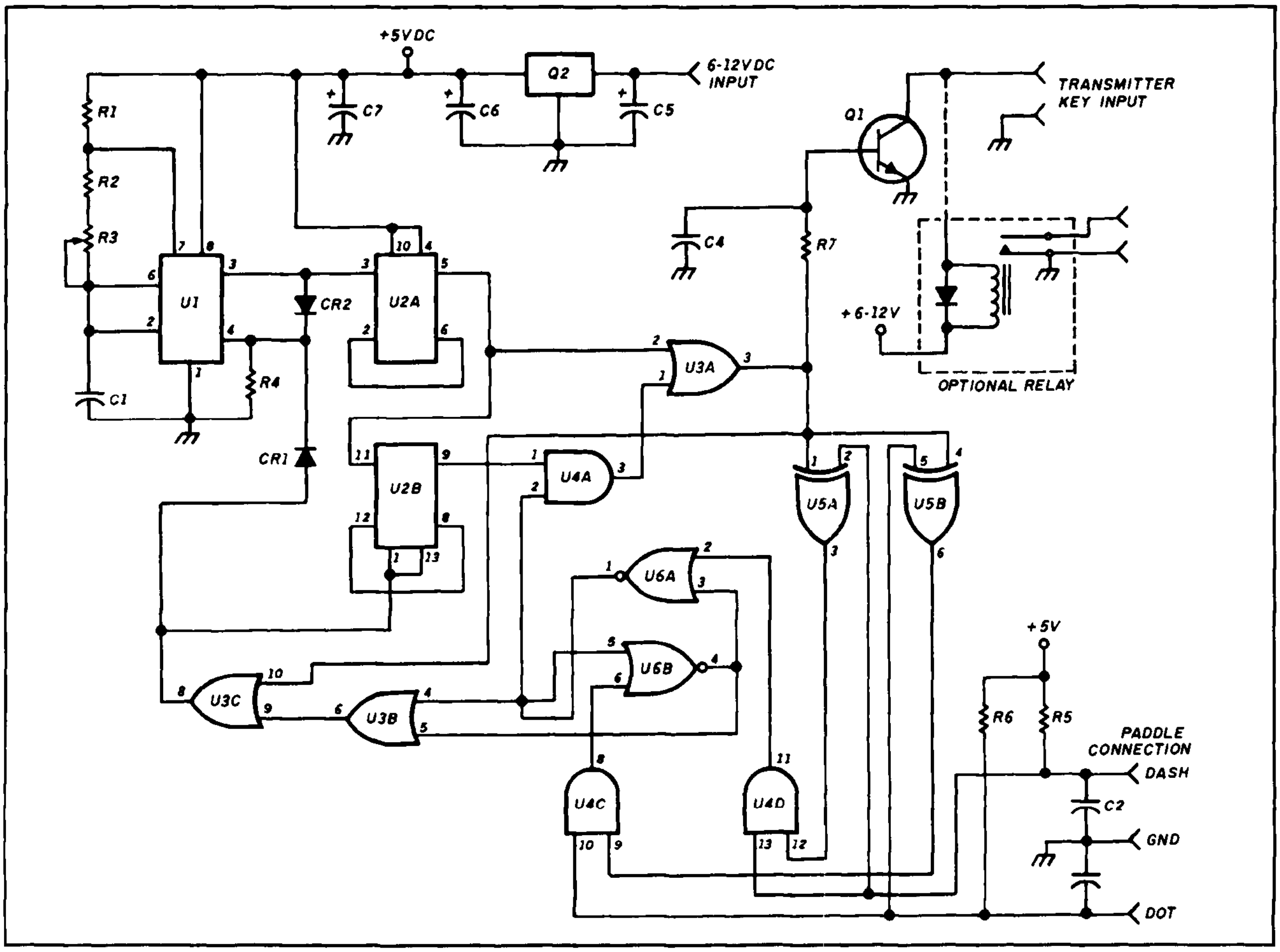
We live in a high tech world. This might lead you to think that, with all the advancement in communications technology, hams would abandon the old low tech modes. But a quick scan of the CW bands tells us that's just not so; they're packed with activity!

I was in grade school when I became a ham. I couldn't afford phone gear, so I spent a lot of time "pounding brass." Even though I now use a state-of-the-art, micro-controlled all band transceiver, you'll still find me down in the CW segments of the bands.

I wanted the feel of an electronic keyer, but money was a consideration when I thought of purchasing one. Instead, I designed one myself and called it the "Digi-Keyer." It uses inexpensive and dependable TTL 7400 series digital ICs.

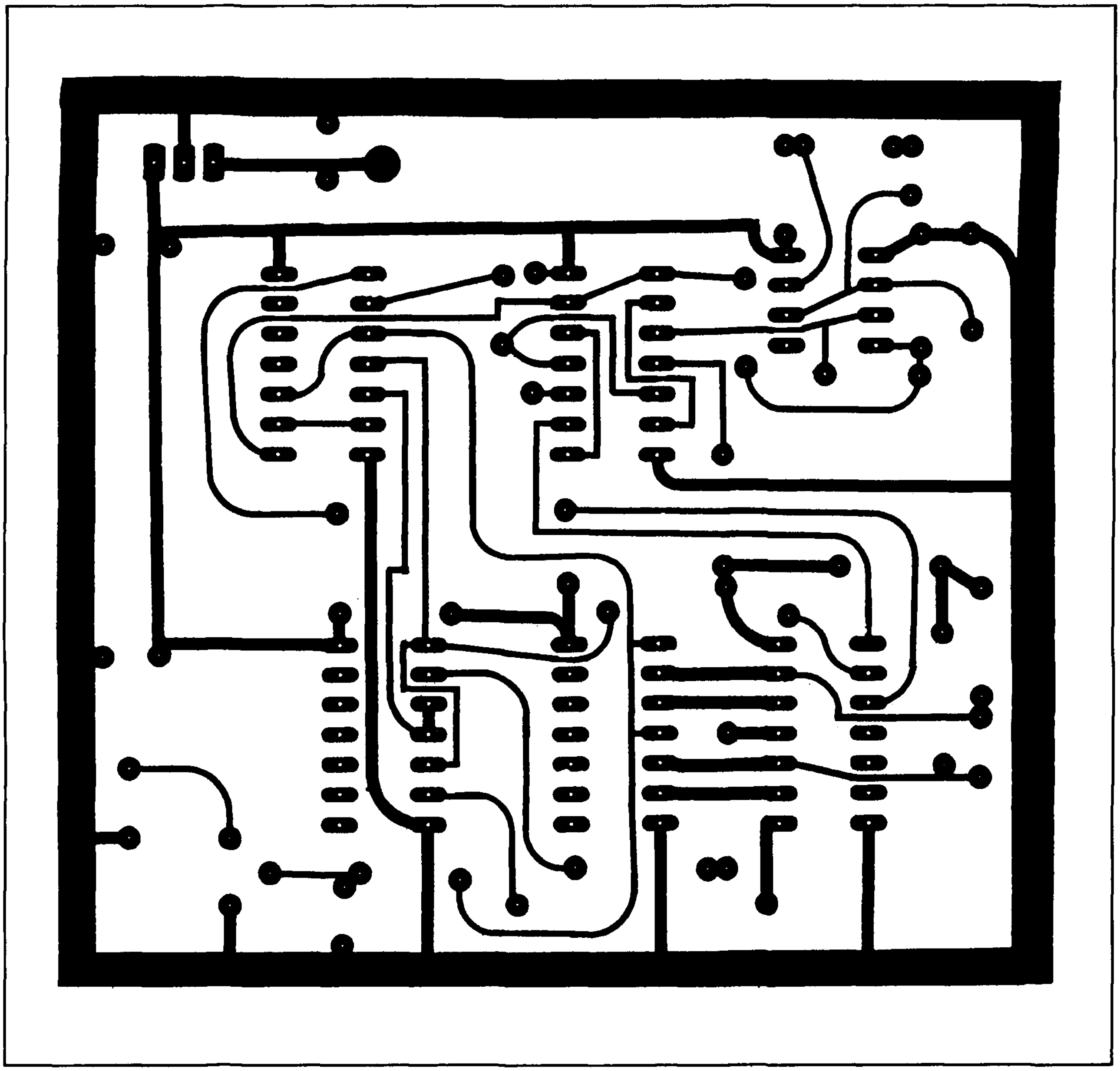
The Digi-Keyer is a no-frills, self-completing dot/dash keyer. It's not iambic, but you'll find it very straightforward. Think of it as an electronic "bug." You press the paddle in one direction for a string of dots and go the other way for a string of dashes. Sorry, there's no squeeze technique here, but it's easy to build and fun to use!

FIGURE 1



Schematic of the Digi-Kayer.

FIGURE 2



PC board layout.

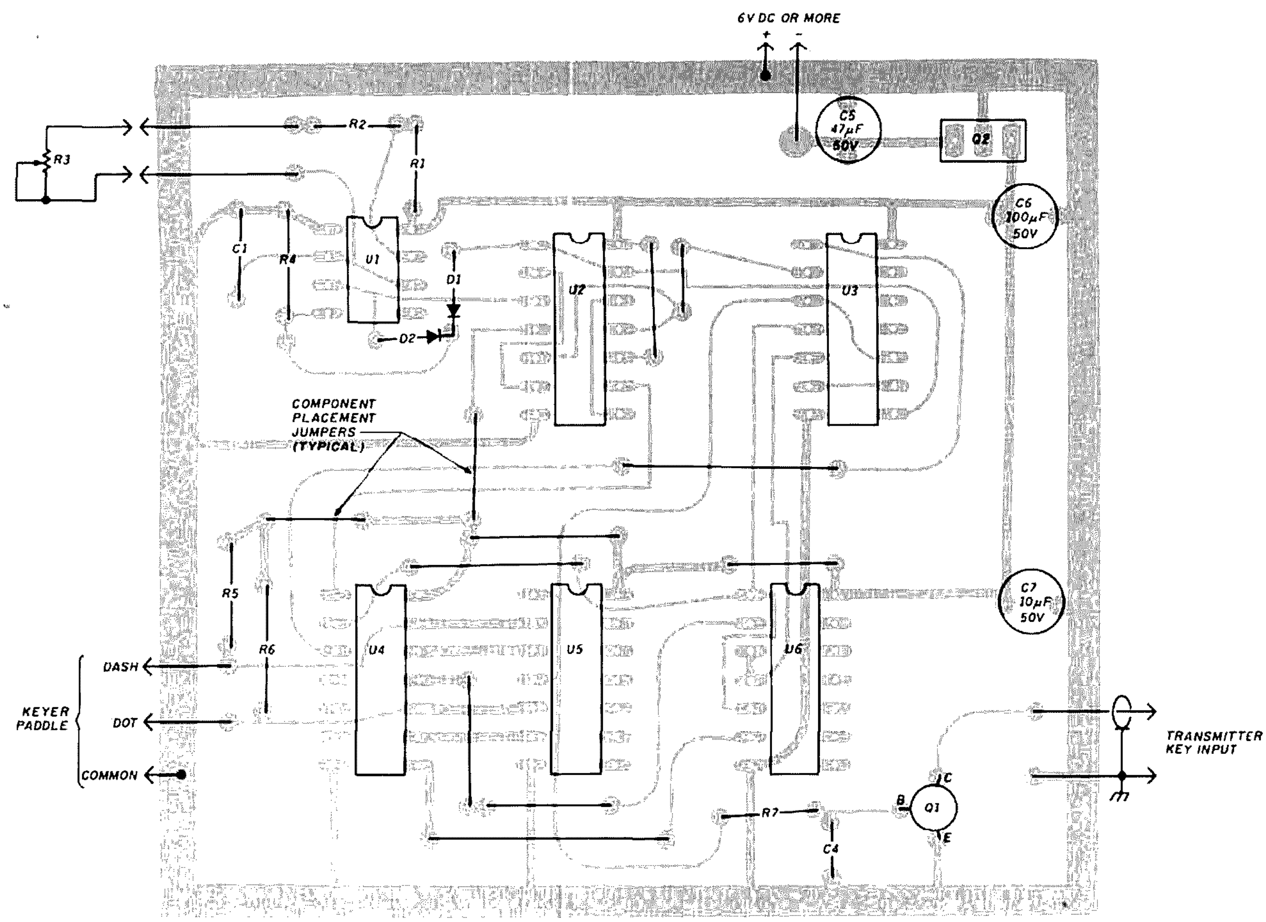
How it works

First, let's analyze the circuit in its idle state to explain its operation. (See **Figure** 1.) U1 is a basic 555 astable oscillator gated by its reset input, pin 4. When this input is low, U1 is in an off condition; when it's high, the timer is free running anywhere from 12 to 42 Hz. When neither paddle is being pressed, both inputs to U4c and U4d are high. One input is high via pull-up resistors R5 and R6; the other is high via gates U5a and U5b, which are also high because of the pull-up resistors (the output of U3a is low at this time). The two highs from U4c and U4d hold the outputs of U6a and U6b low. Because there isn't a high level gated to the reset input of U1 (the astable oscillator), it remains in an off state. The same low level that keeps U1 off, also keeps the two D flip-flops U2a and U2b cleared. The keyer is in a settled state.

Now press the dot paddle. The output of gate U4c goes low, and causes the output of U6b to go high. This high is detected on one input of U6a, causing it to remain low during the dot cycle. It locks out the dash cycle effectively by holding one of U4a's inputs low. The high from U6a is also gated to the clear inputs of U2 and the reset input of U1 via U3b, U3c, and CR1. U1 begins its timing cycle and the output, pin 3, goes high.

This positive-going level reaches the clock input of U2a. The $\overline{Q}$ output is high because U2 was previously in a clear state; this output is presented to the D input of U2a. The high level is clocked through U2a, gated to the output of U3a, and routed back to U1's reset input via U3c — allowing U1 to time out the complete dot cycle.

FIGURE 3



Component placement guide.

PARTS LIST

Capacitors		**Semiconductors**	
C1	1 μF (see text)	Q1	2N2222
C2,C3	0.1 μF	Q2	7805 (5-volt regulator)
C4	0.01 μF	U1	555
C5	47 μF/50 volt electrolytic	U2	7474
C6	100 μF/50 volt electrolytic	U3	7432
C7	10 μF/50 volt electrolytic	U4	7408
		U5	7486
Diodes		U6	7402
CR1,CR2	1N914		
Resistors			
R1	1 k		
R2	22-27 k (see text)		
R3	50 k potentiometer		
R4	4.7 k		
R5,R6	10 k		
R7	4.7 k (see text)		

Let's say you release the dot paddle before the dot is completed. Because you now have two highs at the inputs of U5b, the output of this "exclusive-or" gate goes low, holding U4c low. This keeps U6a low via the U6b latch arrangement, allowing the dot to be completed. When the dot is completed, U3a goes low, causing U1 to stop and U2a and U2b to clear — unless you're holding the paddle, letting the circuit time out and form another dot.

The dash circuit operates in a similar fashion. The exception is that U6a goes high to U4a, causing U4a to gate the output of the second flip-flop (U2b) into U3a. When U2a is clocked by the first pulse of U1, its positive-going output also clocks U2b, placing a high at the latter's output. That high remains for a complete cycle of U2a — the equivalent of two dots. As U2a is going high a second time, U2b is clocked low, but the pulse from U2a is added to the pulse of U2b by way of U3a to create a pulse that's three dots long — or a dash! As with the dot circuit, this cycle will repeat itself if you hold the

dash paddle, or will time out after the completed dash if you release the paddle.

Diodes CR1 and CR2 are essentially gating diodes. I used them because of the overriding function of the reset input of the 555 chip, U1. When the reset goes low, it forces the output low — no matter where it is in the timing cycle. Sometimes a "slap" on one of the keyer paddles produces a pulse that's short enough to prevent the 555 from timing out because of the delay time from reset to output (typically around 0.5 μs). Reset goes low before a pulse can propagate through the circuit. If you use CR1 and CR2, once the output of U1 goes high CR2 will hold the reset input high and CR1 will be forward biased. But if U3c goes low before the output pulse can gate back through to U1, CR1 will become reverse biased, isolating the output of U3c, and allowing the timer to continue its timing cycle long enough for the output to be gated back through U3c. R4 is a pull-down resistor which prevents accidental triggering of U1 when its output is low and the output of U3c is also low. R7 and Q1 are the keying circuit that activates your transmitter.

All Digi-Keyer parts are inexpensive and readily available. If you order from one of the many mail order parts houses, you'll have no problem getting them. The total cost of the parts, if you purchase them through one of these firms, should be under $5.00, minus the pc board, case, and power supply. (See **Figures 2** and **3** for PC board layout and component placement guide.) I use an AC adapter-type power supply that outputs anywhere between 6 and 12 volts DC, with a current rating of 500 mA or more. Use a 7805 three-pin regulator chip to obtain the 5 volts you'll need for the Digi-Keyer. Unfortunately, TTL uses a lot of current, so batteries won't last long.

You can build the Digi-Keyer by mounting the sockets on a perfboard and wire wrapping the circuit. There's nothing critical about the layout. If you decide to use my pc board layout, you won't need the sockets.

R7 is normally a 4.7-k resistor. But if you plan to use a keying relay, lowering R7's resistance will give you more current to pull in the relay contacts. A 47-ohm resistor works quite well for most small relays.

You can vary R2 from 22 to 27 k, depending on the speed range you prefer. For example, a 22 k will give you a speed range from about 10 to 30 wpm. A 27 k gives you a speed range from about 5 to 25 wpm. Be sure that R3 is a linear-taper potientiometer. C1 can be any type of 1-μF capacitor. I tried several kinds, from polystyrene to nonpolarized electrolytics.

I didn't include a space for a keying relay on the pc board layout. A small piece of perfboard, not much larger than the relay itself, will be sufficient to outboard the relay close to the board.

I have found that, in some instances, the keying voltage of some transmitters may be too high for Q1 to handle. Sometimes RF gets into the keyer through Q1, causing the latter to lock on. For either of these problems, I suggest using a keying relay between Q1's collector and the power supply positive. Use a relay whose coil is rated at the voltage of the power supply you've selected to use for the keyer. In worst case situations, place the keyer board in a small metal box (Bud no. CU-234) and ground it to your transmitter chassis.

As I said before, Digi-Keyer operation is simple, straightforward, and fun!

I'd like to thank Ralph Easley, N4UTW, who helped me with the pc board, and Marcus Harton, KC4HVG, for his help editing this article.

publisher's log

Congratulations Terry; apologies Dick

One of the fun parts of managing any business enterprise is to be able to announce the promotion of a valuable team member. If you take a look at this month's masthead you will find that Terry Northup, KA1STC, is now the editor of *Ham Radio* Magazine.

In the two years that she has been with us, Terry has made a most enviable track record for herself. She took on the assignment of refocusing our editorial product to make it more useful to our existing readers and at the same time to make it more appealing to Amateurs who were not already subscribers. The magazine was also to be given a bold new look which would reinforce the message that it was not just business as usual here in New Hampshire.

There was a tremendous amount of work to be done, as no part of the production process was left untouched. The whole *Ham Radio* staff became involved in the many changes that had to be made and everyone certainly deserves a lot of credit. However, it was Terry who had to keep the whole project on track and on schedule.

The results speak for themselves. The magazine you are holding in your hands is a more lively and timely product than ever before. Your many letters and comments have been virtually all in approval. The real proof is that our readership is up over 25 percent in just one year's time, and this growth shows no signs of slowing.

You've earned your new desk, Terry. Thanks both from your teammates and from your many thousands of loyal readers.

On another subject, Dick Ross, K2MGA, my counterpart at *CQ* Magazine called the other day to point out that the name of their magazine and of The CQ World-Wide DX Contest are trademarked and should have been indicated as such in the article published in our August issue. Our apologies, Dick; it won't happen again. All DX editors, please take note.

Skip Tenney, W1NLB

EXTEND YOUR DVM'S MEASUREMENT CAPABILITIES

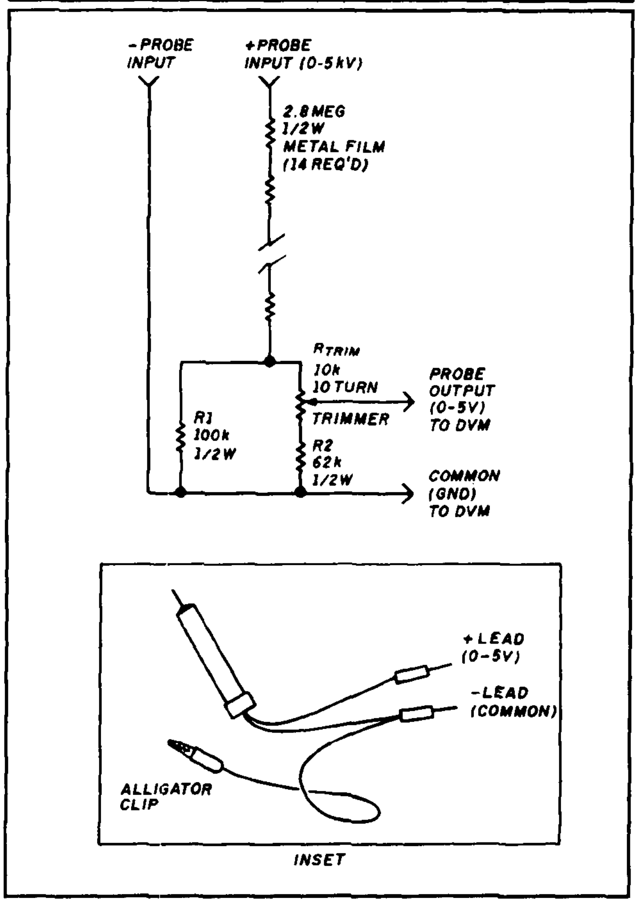
By Ralph H. Fowler, N6YC, Rt. 1 Box 253R, Pearl River, Louisianna 70452

Most of the DVMs offered by today's manufacturers lack the ability to measure voltages higher than approximately 1 kV. Perhaps this is why the old, reliable Simpsons are still so popular. It's as if manufacturers forgot that some people still troubleshoot high voltage equipment like linear amplifiers, tube-type transceivers, and high voltage power supplies. In an attempt to fill this void, I'll show you how to construct a simple, easy to build high voltage probe capable of measuring 5 kV, or more. You can use this probe with any DVM capable of measuring 0 to 5 volts. Almost any reasonable DVM input impedance is allowable, and the basic accuracy of your DVM is preserved after the probe is calibrated.

The schematic of the probe is shown in **Figure 1**. It's essentially a 40-meg string of resistors shunting the measurement voltage, with an adjustable tap near the ground end. When connected to the tap, your DVM will read the voltage out in kVDC, with a scale factor of 1,000. Thus, 3100 volts DC from your linear's power supply will be read out as 3.100 volts DC.

The resistor string in my version is composed of fourteen 2.8-meg 1/2-watt metal film resistors. Metal or film resistors are preferred over composition types because the latter have poorer stability, and the accuracy of readings is apt to degrade over time — requiring recalibration. With an input of 5 kV, each resistor sees less than 360 volts, which is well within the manufacturers' ratings. Manufacturers typically rate 1/2-watt carbon composition resistors at 350 volts continuous, and metal film resistors at up to 900 volts. Power dissipated with 5 kV applied is less than 0.64 watts total, a very conservative condition. You need not duplicate my particular resistor values, nor do all the resistor values have to be the same. More importantly, the voltage (across EACH resistor, calculated individually if the values are not all the same), dissipation, and stability factors should be consid-

FIGURE 1



Schematic of the 0 to 5 kV high voltage probe.

ered. Don't run the risk of subjecting your sensitive DVM to the ravages of high voltage.

One feature worth incorporating is the redundancy of the paralleled resistors near the ground end of the string, R1, R2, and Rtrim in **Figure 1**. Note that should any one of these resistors open, for whatever reason, the voltage presented to the DVM will not soar up to 1kV (with 5 kV applied to the input) and cause meter breakdown. Though it probably wouldn't damage most DVMs with typical protective circuitry, why tempt fate?

This probe works with meters of various input impedances because the tap is at a fairly low impedance point on the string. The shunting action presented by meters with 1 meg or higher impedance is negligible. I chose the values used here for a 10-meg input impedance, although this circuit will accommodate anything above approximately 1 meg. To accommodate significantly lower impedances, it may be necessary to change the string and/or tap position on the string. In any case, Rtrim allows exact calibration for your particular DVM.

Construction

The probe is built on a 5-1/2" by 5/8" piece of perfboard, as shown in **Figure 2**. Do not use prototype pc boards, or any other noninsulating board. The high voltage may lead to breakdown. The perfboard is housed in a 7" length of 3/4" rigid PVC pipe with a cap (uncemented) on the lead exit end. The probe end has a probe tip cemented in place with epoxy. After the components are in place inside the housing, stuff a tuft of fiber glass insulation or other nonflammable insulator around the probe tip and approximately 1/2" inside the probe housing. Backfill the remaining 1/2" void around the probe with epoxy or urethane cement to secure the tip in place. To provide some strain relief for the cable/perfboard connection point at the lead exit end, anchor the leads to the end plug with tape or cement. Two leads exit from the rear of the probe housing. One is connected to the tap on Rtrim, and goes to the "+" input of the DVM. The other is the common lead, which connects to the "−" input of the DVM. I used miniature coax to reduce the tangle of cables. A third lead originates from the "−" plug, which attaches to the common (ground) point in the circuit you are probing. This is shown in the **Figure** 1 inset.

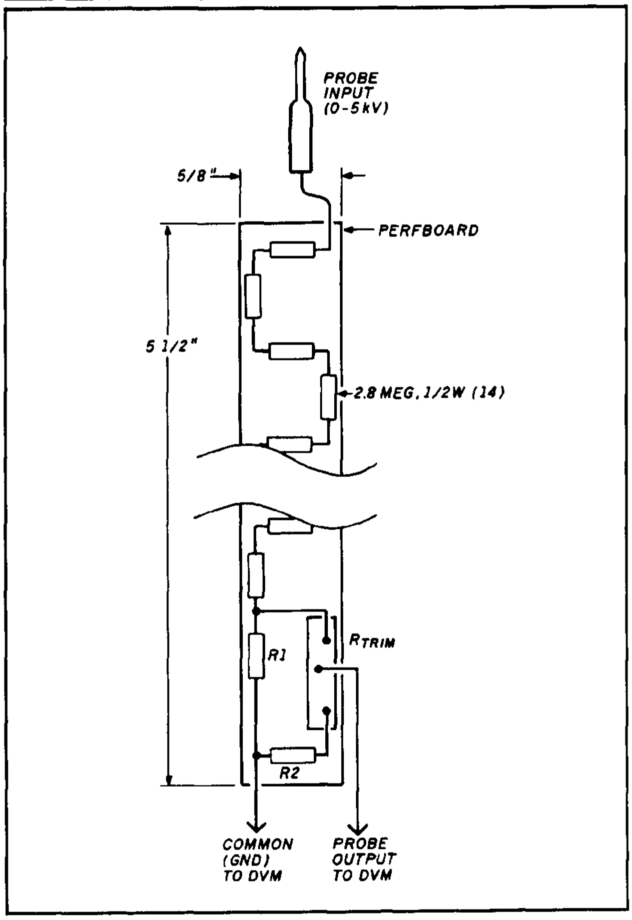
I found that the "zigzag" pattern of resistor mounting shown allows for reasonable parts placement with a minimum of probe length. The tubing I used for my probe is 0.185 inch thick and marked "suitable for drinking." Since rigid PVC has an advertised dielectric strength of 350 volts per mil thickness*, it will (theoretically) withstand about 32 kV with 100 percent safety factor. This is at DC or low, non-RF frequencies, however, so don't use this probe with RF present at an appreciable power level (like at tube anodes).

Calibration

Calibration is simple and can be done in either of two ways.

Method 1: If possible use a second, accurate meter capable of reading, say 1 kV, as a reference. Simply adjust Rtrim so your probe/DVM reads the same as the reference meter when connected to a suitable high voltage source. Remove the end cap and use an **INSULATED** tweaking tool to do the Rtrim adjustment.

FIGURE 2



Suggested parts layout on the perfboard.

Method 2: The second method requires only one meter capable of measuring a few volts accurately. It can be the meter you plan on using with the probe.

First, determine the resistance of the R1, R2, Rtrim series/parallel combination by measuring from point A to ground (see **Figure 3**). If you use precision resistors, calculate their resultant value. My resistor configuration measured 41.860 k.

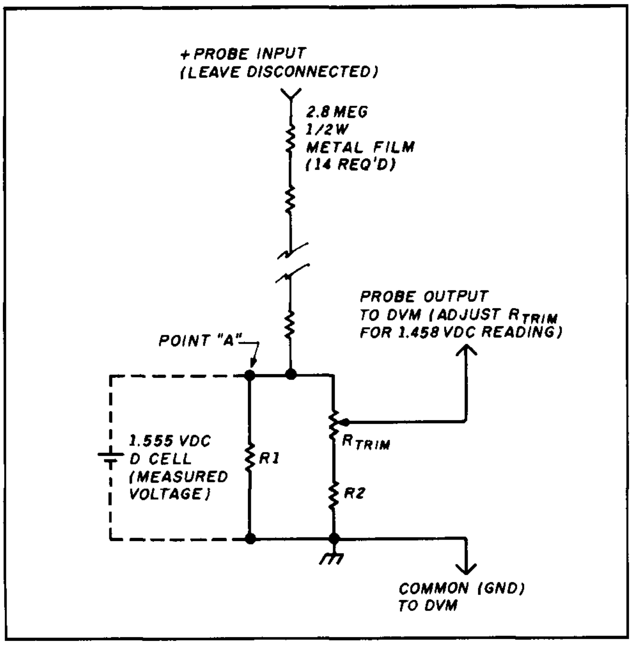
Next, obtain a stable, low voltage source (like a 1.5-volt cell) whose voltage is known, or can be measured accurately. I used a D cell with a measured voltage of 1.555 volts DC, open circuit.

Finally, refer to **Figure 3**. Notice that if 1.555 volts DC from the source is applied between point A and ground, by Ohm's law a current of 37.15 μA will flow through 41.860 k. Note that the same current would also flow if 1458 volts DC were applied to the probe input. By applying 1.555 volts DC between point A and ground (with the probe output connected to your DVM), you simply adjust Rtrim to get a 1.458-volt reading on the DVM, corresponding to an equivalent of 1458 volts at the probe input. **Figure 3** shows this calibration setup.

One operational note remains. Some meters have differ-

*According to ARRL Handbook, 1986 Edition, page 35.

FIGURE 3



Simple setup for calibrating the probe.

ent DC and AC input impedances. Ten-meg DC and 1-meg AC input impedances are sometimes specified. In this case, if you calibrate with a DC voltage on the DC scale, AC voltages will be approximately 3.6 percent too low as a result of changing impedances. I think most of us can live with this; but if you're a perfectionist, you can calculate the error in volts and add this number to your reading.

A final safety note: While a HV probe increases your measurement capability, remember it also increases your risk of lethal shock. **ALWAYS** exercise **EXTREME** caution while working around high voltages.

And there you have it. A cheap, simple and accurate HV probe. Happy measurements!

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PEP WATTMETER

By Thomas V. Cefalo, Jr., WA1SPI, 29 Oak Street, Winchester, Massachusetts 01890

Peak envelope power (PEP) can't be measured easily with an analog meter. This meter doesn't respond well to the dynamic variations in the human voice. As an alternative to the analog meter, you can use an LED bar display to monitor output power. The LED indicates actual peak power, eliminating the problems you'd experience with the analog meter. This article describes a PEP wattmeter designed for use with a transceiver or linear amplifier with an LED display having power ranges of 30 to 160 and 300 to 1600 watts.

Sampling power

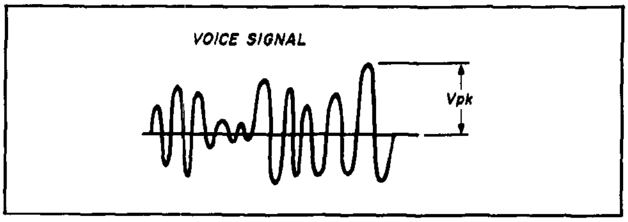
PEP is probably one of the most misunderstood terms in Amateur Radio. A modulated signal composed of two or more tones results in a complex sinsoidal wave. However, the variation from cycle to cycle is small, so you can use sine wave measurement techniques (see **Figure 1**). The actual PEP is the *rms power* contained in a signal at the peak of the modulation envelope. Calculate PEP using **Equation 1**.

$$PEP = \frac{(0.707 \cdot Vpk)^2}{RL} \quad \textbf{(1)}$$

The problem lies in determining how to sample a small percentage of power from a transmission line. One approach is to simply tap off the transmission line with a resistive divider. This itself presents two major problems. First, the impedance of a carbon resistor isn't constant over frequency. A model of a carbon resistor is shown in **Figure 2**. The inductance is caused by lead length. If you have short leads, you can ignore this inductance in the HF spectrum. The main contributor of reactance is capacitive in the one-half watt and larger wattage resistors. This is because of the capacitance formed between the carbon granules. For example, I measured the series resistance and parallel capacitance of a 10-k, 1-watt carbon resistor over frequency on a Hewlett Packard RF impedance analyzer model 4191A and plotted it in **Figure 3**. The graph indicates that the resistive divider is a poor way to sample power.

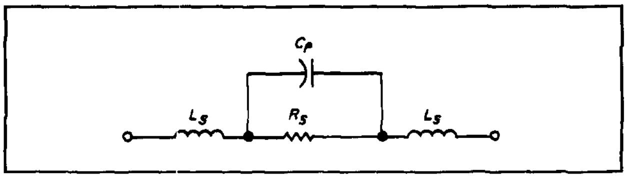
The second problem that occurs with a resistive divider has to do with isolation. There's no isolation between the forward and reflected wave. This means that any VSWR on the transmission line causes the forward power to add with the reflected power, giving a false power reading. To obtain an accurate power reading, the VSWR on the transmission line must be less than or equal to 1.1:1.

FIGURE 1



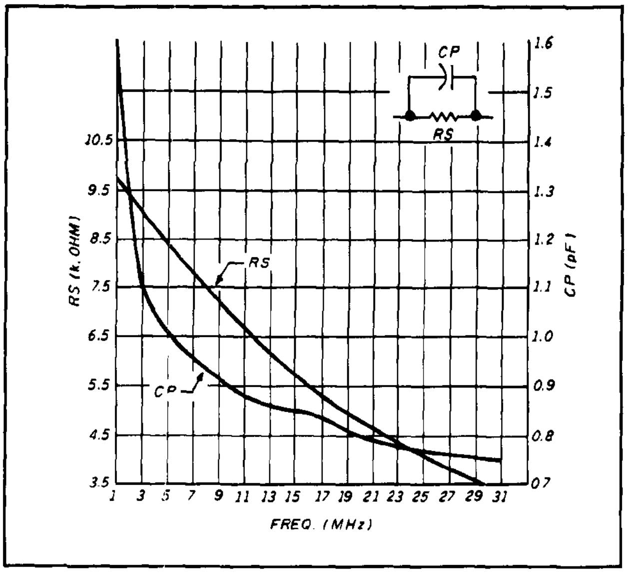
Signal sample showing voice peaks.

FIGURE 2



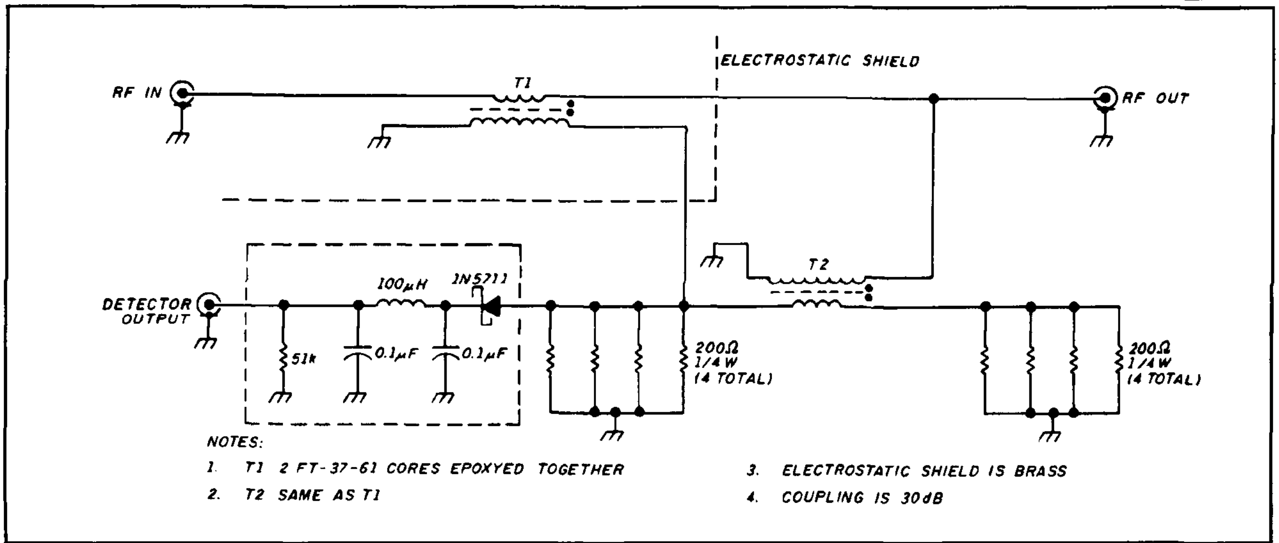
Carbon resistor equivalent circuit.

FIGURE 3



Graph showing series resistance and parallel capacitance variations versus frequency.

FIGURE 4



Schematic of the dual directional coupler.

PARTS LIST

Dual directional coupler	
Capacitors	
2	0.1 μF
Inductors	
1	100 μH
Resistors	
8	200 ohm, 1/4 watt
Semiconductors	
1	1N5711

A dual directional coupler eliminates all the ailments of the resistive divider. The coupler is a device that samples the forward power, but is insensitive to reflected power. This is referred to as the directivity, which is the isolation between the forward and reflected ports. The variation of coupling is flat when used over the specified bandwidth (unlike the resistive divider). Because the insertion loss is very small, a coupler can be connected directly in series with a transmission line. A single directional coupler would be sensitive to VSWR because of inadequate isolation.

30-dB dual directional coupler

The dual directional coupler used with the PEP wattmeter is a modified version of one that appeared in *Ham Radio*.[1] Because the coupler can be used with a 2-kW linear amplifier, 1/1000 of the RF power is sampled — so I chose a 30-dB coupler. To increase the power-handling capability, I epoxied two cores together. I used Amidon FT-37-61 toroidal cores with a permeability of 125. Core dimensions are 0.125″ thick, 0.187″ ID, and 0.375″ OD. The primary of each transformer is a 1-inch piece of 0.141″ OD semi-rigid coax cable passed through the center of the core. Only one side of the shield is soldered to ground. The secondary of each transformer has 31 turns of no. 30 AWG enameled wire evenly spaced and epoxied to the core upon completion of the coupler. Remember that you make a turn each time the wire passes through the center of the core. For more information on dual directional couplers see **References** 2 and 3.

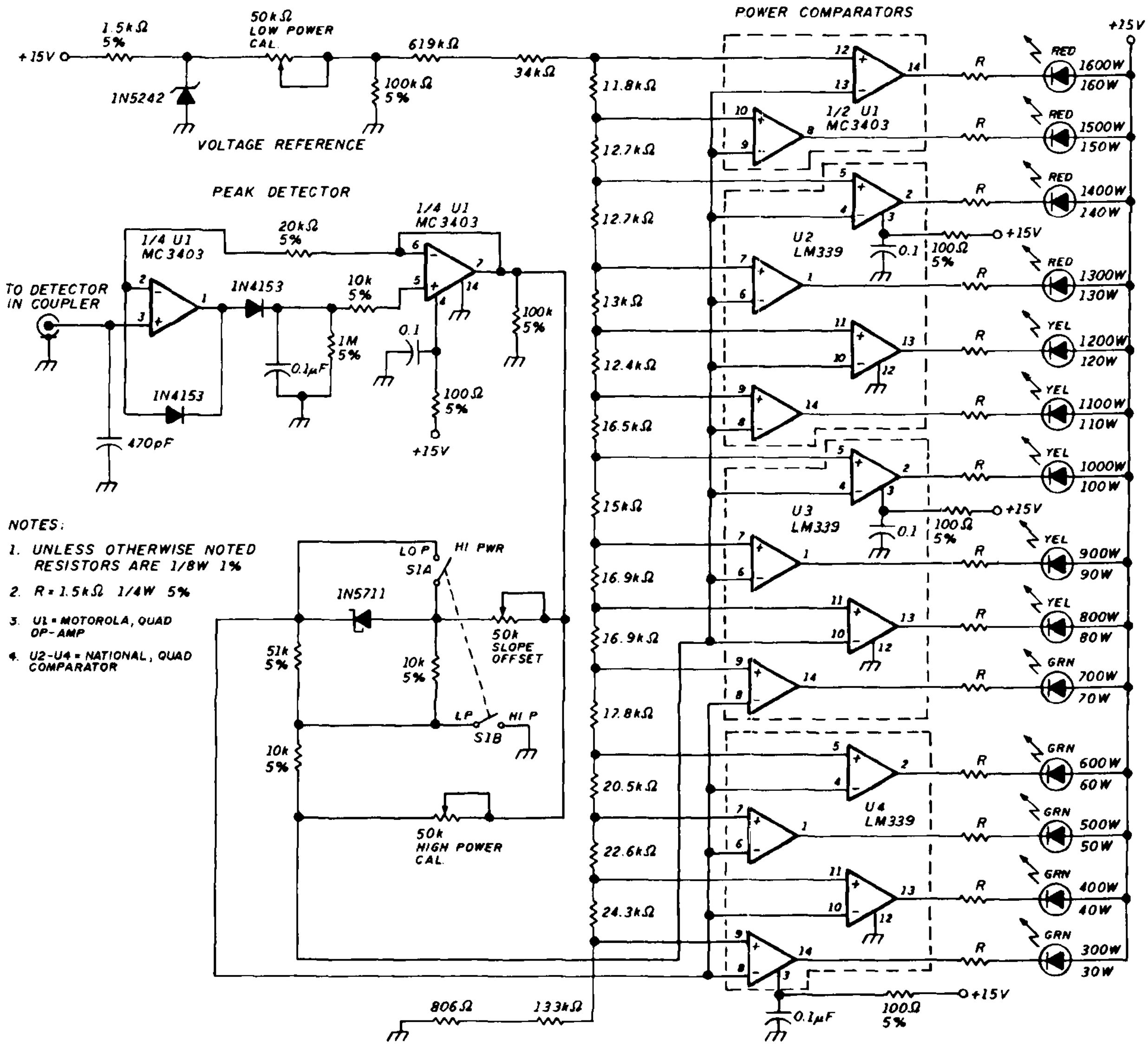
The actual coupling is 29.9 dB ± 0.1 dB from 1 to 30 MHz; the 3 dB point is at 55 MHz. I measured the self-resonant frequency at 77 MHz. Directivity is 35 dB at 1 MHz and rolls off to 20 dB at 30 MHz. The insertion loss is 0.06 dB. **Figure 4** shows the directional coupler and detector.

Theory of operation

The coupler samples a signal from the transmission line and the diode detects the positive peaks. I chose a Schottky diode because it's more sensitive and stable than a germanium. The RF is filtered and the video portion is applied to the input of a peak detector. As the detected voltage slope rises, the op amp drives the series diode on, and the capacitor is charged to the peak of the input voltage. When the detected voltage reverses its slope, the capacitor is left in a charged state. The discharge time is determined by the resistor in parallel with the capacitor. On the negative-going slope, the op amp switches the series diode off and the peak voltage across the capacitor is applied to the input of a buffer. The buffer also provides input bias current for the op amp. With no signal applied to the peak detector, the feedback loop opens. In this state, the resistor in the feedback loop allows the op amp to be clamped in the off state by the diode connected at the inverting terminal. This leads to a faster recovery and prevents op amp saturation.

The buffer output is fed to a voltage divider network. In the low position, the diode is shorted and the divider network is switched above ground. Because the comparators have high input impedance, the series resistors in the divider won't attenuate the signal in the low power position. In the high power position, the diode is switched in and the resistors in the network are grounded. The signal is now divided down to the low power voltages. To increase accuracy below 800 watts on the high power scale, a diode

FIGURE 5



Schematic of PEP Wattmeter.

PARTS LIST

PEP wattmeter

Capacitors	
5	0.1 µF
1	470 pF
Resistors	
4	100 ohm, 5 percent
15	1.5 k, 5 percent
3	10 k, 5 percent
1	20 k, 5 percent
1	51 k, 5 percent
3	50-k potentiometer
2	100 k, 5 percent
1	1 meg, 5 percent
1	11.8 k
2	12.7 k
1	13 k
1	15 k
1	16.5 k
2	16.9 k
1	17.8 k
1	20.5 k
1	22.6 k
1	24.3 k
1	34 k
1	133 k
1	619 k
1	806 k
LEDs	
5	green
5	yellow
4	red
Semiconductors	
1	1N5242 zener
2	1N4153
1	1N5711 Schottky
1	MC3403
3	LM339

is used to reproduce the same slope as the low power scale. The output of the divider network is applied to the inverting inputs of the comparators.

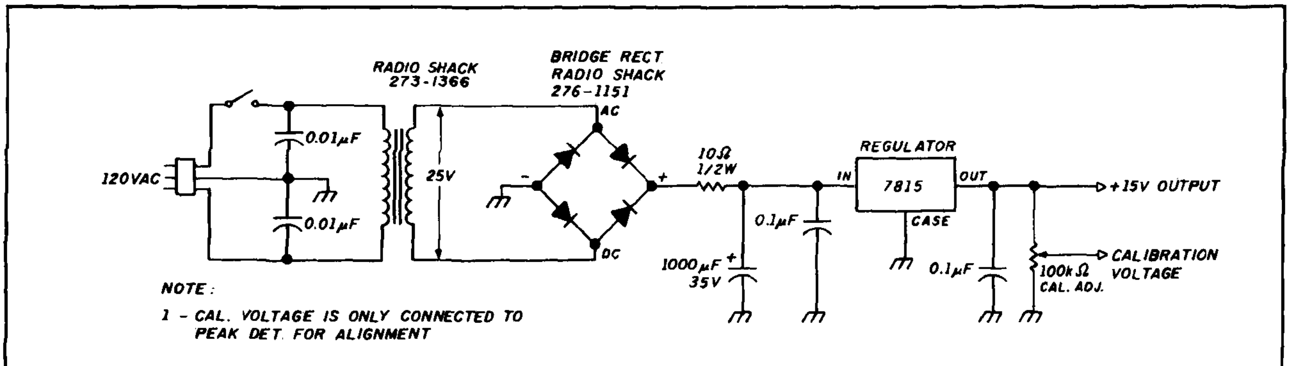
The reference vollages are derived from a ladder network composed of 1-percent resistors. The tap point voltages take the voltage drop in the detector diode into account. Each tap is connected to a noninverting input of a comparator. When the output voltage of the peak detector is greater than the reference voltage, the output of that comparator switches to an active low. The LED is now forward biased and turned on, indicating the PEP being transmitted. The wattmeter is shown in Figure 5.

Construction

The directional coupler is constructed on a 2 × 2 × 0.062" double-sided piece of G10 board. I cut square holes in the board for toroid clearance so the semi-rigid coax could lie flat on the board. Each center conductor of the semi-rigid was soldered to small standoff terminals. I enclosed the board in a 4 × 2-1/2 × 1-5/8" CU-2102-B Bud minibox with panel mount SO-239 connectors on each side. You should use RG/8U (or any type of 50-ohm coax cable that will handle the high power levels) between the coupler board and the SO-239 connectors.

The detector is built into a small enclosure made from brass and placed within the minibox to shield it from the RF. The coupler and detector are placed in a separate enclosure so they can be connected remotely from the watt-

FIGURE 6



Schematic of power supply.

PARTS LIST

Power supply

Capacitors

2	0.1 µF
2	0.01 µF
1	1000 µF, 35-volt electrolytic

Resistors

1	10 ohm, 1/2 watt
1	100-k potentiometer

Semiconductors

1	Bridge rectifier (Radio Shack P/N 276-1151)
1	15-volt regulator (7815)

meter. The separate enclosure also achieves greater isolation.

The wattmeter is housed in Radio Shack enclosure no. 270-272. Its dimensions are 1-15/16 × 8-1/4 × 6-1/2". I built the peak detector and comparator circuits on a vector pc board. Because the signals of this circuit are low frequency, I used point-to-point wiring. The LEDs are mounted in a straight row across the front panel. The power supply was built on a pc board using small standoff terminals. The power supply schematic is shown in **Figure 6**.

Alignment

Calibrate the wattmeter with the DC power supply and a voltmeter. First remove the coupler and connect the output of the calibrator to the input of the peak detector. Connect a voltmeter to pin 7 of the MC3403 and switch the wattmeter to low power. Increase the calibration voltage until the voltmeter indicates 2.711 volts. Adjust the low power pot so the 100-watt LED just comes on. Now switch to high power and increase the calibration voltage until the voltmeter indicates 7.673 volts. Next adjust the slope offset pot until the 700-watt LED just comes on. Finally, increase the calibration voltage so the voltmeter indicates 9.27 volts and adjust the high power pot until the 1000-watt LED just comes on. You can also align the wattmeter by applying a CW signal to the coupler. Using the same power levels, adjust the power calibration pots in the same sequence you used for the DC alignment.

Conclusion

I tried different time constants to produce a fast attack and slow decay. A 1-second time constant gave the best results. This let the LEDs stay on long enough for me to see, and still let them track the response of the human voice. I used the wattmeter with a 2-kW linear amplifier; the coupler cores showed no of evidence overheating. I checked the calibration using a Hewlett Packard model 436A wattmeter. The maximum error for the low and high power scales was 2 percent.

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2. John Grebenkemper, KA3BLO, "The Tamdem Match — An Accurate Directional Wattmeter," *QST*, January 1987.
3. Robert S. McDonald, WB7CLV, "Low Cost, Wideband Dual Directional Coupler," *RF Design*, May/June 1982.

TS-950S *(continued from page 29.)*

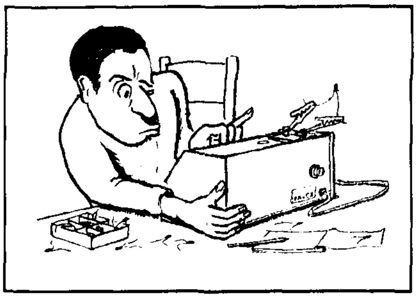
second IF (455 kHz) filter indicators are on the right. You can select a number of different filter combinations by pressing the appropriate buttons just below the indicator lights. For example, I tried the 500-Hz first IF filter in conjunction with the 250-Hz second IF filter. This combination let me copy a weak DXpedition through a relatively unruly pileup without much trouble. I then switched to 2.7-kHz filters in both IFs to scan around the band for other stations. This is a nice feature, and I'm glad to see it added to the TS-950S.

Another feature I really liked is the subreceiver. I left it tuned to the pileup I had been monitoring while I listened up and down the band with the main receiver. In a contest you can run stations on VFO A and, at the same time, search for new multipliers on the subreceiver. When you find one, enter the frequency into VFO B and give the station a call. After working him, select VFO A again and continue to run stations. The subreceiver must operate within 500 kHz of the main receiver. While this means you can't monitor two bands simultaneously, this isn't a major limitation for most operators. The subreceiver uses a fixed 2.7-kHz bandpass filter.

Getting a preview of a new radio is fun. Getting to operate it before it reaches the marketplace is a special treat. Kenwood estimates delivery of the TS-950S to dealers within a few months. The list price is currently unavailable. Stay in touch with your favorite Kenwood dealer for final pricing and availability.

Practically Speaking

By Joe Carr, K4IPV



VERTICALLY POLARIZED HF ANTENNAS: PART 3

In the first part of this three-part series, I examined the basic theory of vertical antennas. In part 2, I developed the theme further by looking at the construction, mounting, and grounding of verticals. In this third and final part, I'll look at the 5/8-wavelength vertical (including shunt-feed alternatives to the series feed normally used on vertical antennas) and a safety issue.

Five-eighth wavelength verticals

Figure 1 shows the configuration for the 5/8-wavelength vertical antenna. Such an antenna generally gives a lower angle of radiation than the more common 1/4-wavelength radiator, so, presumedly, it's better for long distance work.

The radiator of this antenna is made from 1/2 to 2-inch aluminum tubing. (Remember that adjacent sizes fit together snugly to form longer sections.) The physical length of the 5/8-wavelength radiator is found from:

$$L(ft) = \frac{585}{F(in\ MHz)} \qquad \textbf{(1)}$$

The radials are the usual quarter wavelength, made of no. 12 or no. 14 copper wire. This length is found from:

$$L(ft) = \frac{246}{F(in\ MHz)} \qquad \textbf{(2)}$$

The feedpoint impedance of the 5/8-wavelength antenna isn't a good match for the ordinary coaxial cables routinely available on the Amateur market. You'll need some form of impedance matching.

One option is to use a broadbanded RF transformer like the Palomar Engineers, Inc. models shown in part 1. These transformers will work throughout the HF spectrum, and match a wide variety of impedances to the 50-ohm standard system impedance.

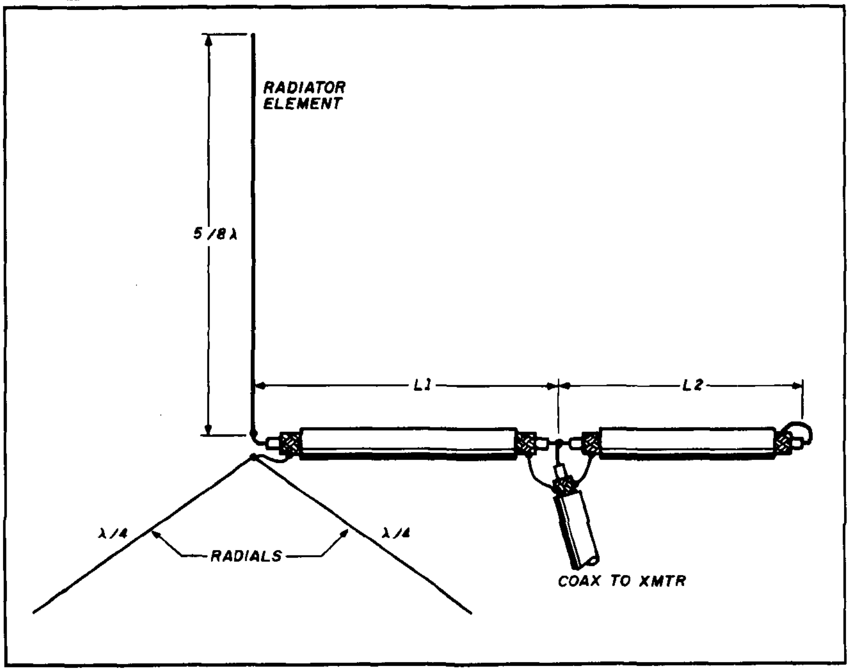
Another option, especially for a single band antenna, is to use a coaxial cable impedance transformer like the one shown in **Figure 1**. The transformer consists of two sections of coaxial cable joined together. These sections appear as L1 and L2 in **Figure 1**. The length is found from:

$$L1 = \frac{122}{F(in\ MHz)}\ feet \qquad \textbf{(3)}$$

and,

$$L2 = \frac{30}{F(in\ MHz)}\ feet \qquad \textbf{(4)}$$

FIGURE 1



Basic configuration for a 5/8-wavelength vertical antenna.

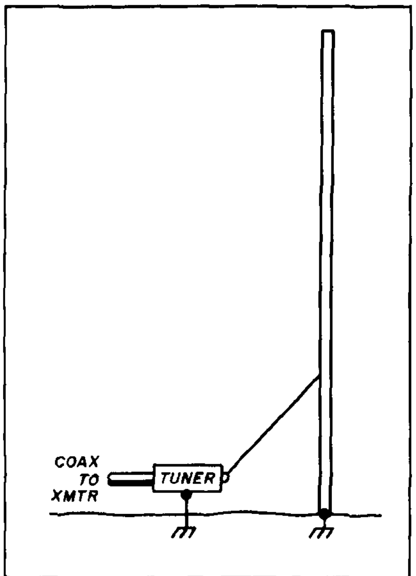
Grounded vertical antennas

The vertical antennas I've presented in this series so far are called *series-fed verticals* because the generator is esentially in series with the radiator element. Such antennas must be insulated from ground. The other class of vertical is the *shunt-fed vertical*, which is grounded at one end (see **Figure 2**). There are three methods of shunt feeding a grounded vertical antenna: *delta*, *gamma*, and *omega*. All three matching systems have exactly the same function. They form an impedance transformation between the antenna radiation resistance at the feedpoint and the coaxial cable characteristic impedance, and cancel any reactance in the system.

The delta feed system is shown in

Figure 2. A taut feed wire is connected between a point on the antenna, which represents a specific impedance, and an antenna tuner. This feed method is common on AM broadcast antennas (usually, or perhaps always, verticals). Although you'd think that the sloping feed wire would distort the pattern, that's not the case. The distortion of the pattern, if any, is very minimal and negligible.

FIGURE 2



Shunt-fed vertical using the Delta match.

The gamma feed system is shown in Figure 3. Since Amateurs commonly use this method to feed Yagi beam antennas, it's a familiar one to most of us. The feed system consists of a variable capacitor to tune the system, and a matching rod that parallels the antenna radiator element. It's important that the rod not be anywhere near a quarter wavelength, or it will become a vertical antenna in its own right. In fact, it would resemble the so-called J-pole antenna. The omega feed shown in Figure 4 is similar to the gamma match, except that you use a series-shunt capacitor network.

Safety first!

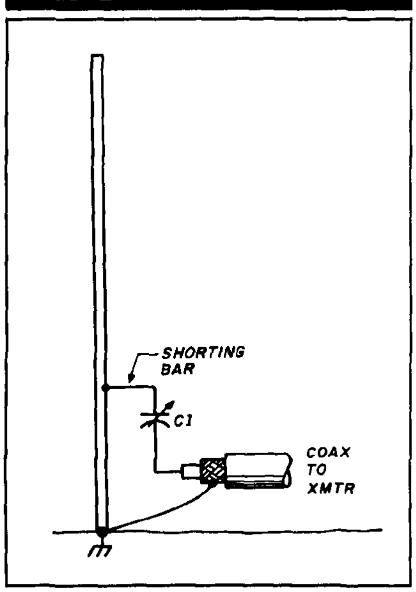
Rarely does a year go by that we don't hear of an Amateur killed by ill-advised antenna installations. There are always stories (fortunately, not always regarding fatalities) about how inept antenna installations cause property damage or, worse yet, serious injury. There are several issues involved. A standard HF vertical is 18 to 27 feet high. When installed on a mast, the total antenna height may be 50 to 60 feet. Having antennas this tall can lead to serious problems. *Before erecting your antenna, be sure that it won't fall onto power lines if it gets away from you.* Also, be aware of windows and other objects the antenna may damage if it falls, and make plans to avoid that problem.

There's a no-nonsense, common sense, two-person rule that you should follow when erecting antennas: *Aways use two or more physically fit people when installing a vertical antenna.* These antennas aren't terribly heavy on the ground, so you might get the false impression that handling one is going to be easy. But try holding onto the lower end of a 20-foot high aluminum "wind sail" while standing on a ladder; even the slightest breeze can become terribly dangerous! You'll also find that normal antenna motions ("wiggle") become serious when amplified by a 20-foot lever arm. I made that foolish mistake one Thanksgiving day, and I'm thankful that my father-in-law showed up in the nick of time to help steady a 37-foot high vertical, plus mast.

Another safety issue is illustrated in Figure 5. Although it doesn't pertain to vertical antennas exactly, it's nonetheless an antenna safety issue. My friend from Novice days, Doug (now EI2CN), has a slip-up tower from his beam. He told me about something called the "guillotine effect." I didn't think much about this problem until, on one of my business trips, I read about a professional tower rigger for a two-way radio company who'd had an arm amputated after it was crushed while he was climbing a slip-up tower. Apparently he failed to use the safety stops provided on the tower, and it collapsed while he was on it. The center section came slicing down, crushing his arm so badly that the surgeons couldn't save it.

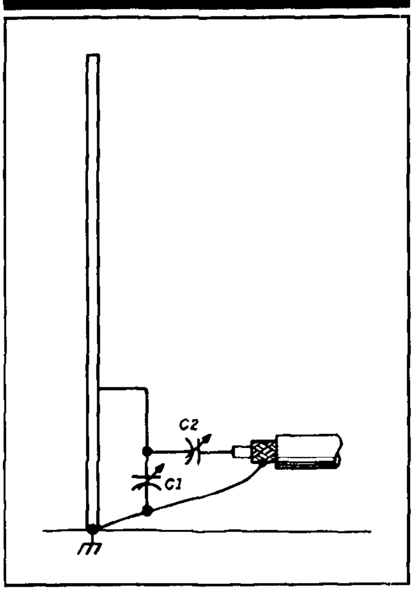
A slip-up tower lets you do your maintenance closer to the ground. So why would you be at risk of being crushed? There are two reasons. First, even if your tower is collapsed completely, it's possible for the antenna to shift downward a couple of inches — especially if a physical failure is present. Second, it's easier to do some types of work on the tower while it's in an upright position. For example, repairing a coaxial line or damaged gamma match is easier with the tower in place. Sometimes, it simply seems like too much trouble to release the guys and crank down the tower. Some Amateurs also ignore the manufacturer's directions and climb the tower. Those who insist on tackling this type of job by climbing the tower are better off double rigging it for safety. But you'll need more than the mechanisms provided by the manufacturer.

FIGURE 3



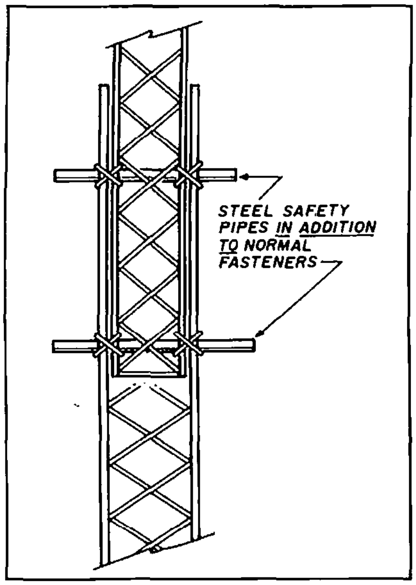
Shunt-fed vertical using the Gamma match.

FIGURE 4



Shunt-fed vertical using the Omega match.

FIGURE 5



A means of providing additional safety precautions when working with a slip-up tower.

Figure 5 shows a tower that's safety rigged to protect against failures. A pair of heavy wall steel pipes are inserted across the tower, impeding the center section. These pipes can be bolted or tied securely in place, and should be used *in addition to any fasteners or safety features provided by the tower manufacturer.* Do not defeat the builder's safety features.

Wear two leather safety belts, not one. Always make sure one of the belts is connected; don't depend on your own physical strength to stay on the tower.

I can be reached at POB 1099, Falls Church, Virginia 22041; I'd like to have your comments and suggestions for this column.

I SAY AGAIN, YOUR KITE ANTENNA CAME DOWN IN MY YARD AND YOU CAN PICK IT UP AT....

✓ 165

(continued from page 52.)

ings decrease friction and load transfer to the gear set. The OR-2300 is available through dealers. The suggested retail price is $859.

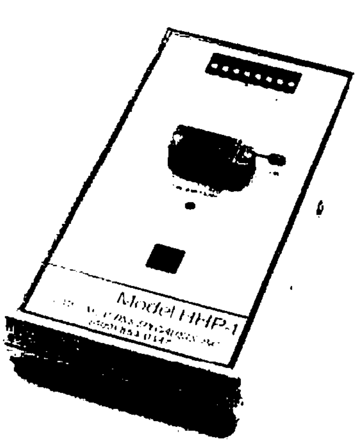
For details contact Orion Business International, Inc., PO Box 9577, Canoga Park, California 91309. Phone: (818)888-4927.

Circle #000 on Reader Service Card.

Handheld Programmer

Communications Specialists, Inc. has announced the HHP-1, a new handheld programmer. This device is designed for custom programming of tones into memory in the Communications Specialists IC-110 custom microcircuit.

The IC-110 microcircuit allows complete flexibility of tone choice and offers accuracy and stability.



The working frequency for these tone products is programmed via a DIP switch on the tone board. With a changeable memory you can choose any nonstandard tone frequency. When you customize the arrangement of the tones, multiple tone switching with one tone unit can be done without diode network circuitry.

The HHP-1 operates on a 9-volt battery (supplied), and measures only 4 × 7-1/2 × 1-3/4 inches. A plug-in socket is provided for external power. The HHP-1 is priced at $199.95. Communications Specialists' standard one-year warranty applies.

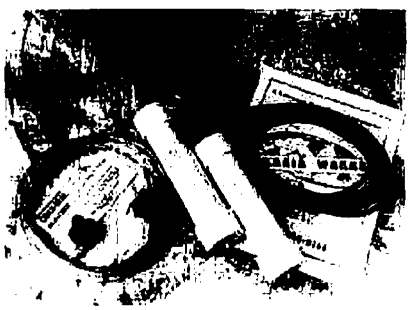
For further information, contact: Communications Specialists, Inc., 426 West Taft Avenue, Orange, California 92665-4296. Telephone: (800)854-0547 or (714)998-3021 (local). FAX (714)974-3420.

Circle #307 on Reader Service Card.

Carolina Windom/2

The CAROLINA WINDOM/2© is a half-size 40-10 meter version of the CAROLINA WINDOM©. It covers seven HF bands, including all of the WARC bands. Performance equals the full-size CAROLINA WINDOM on all of the bands covered.

The CAROLINA WINDOM/2 is fed with 50-ohm coaxial cable. A transmatch is required on all bands. Each antenna comes assembled and complete with special dedicated matching unit,



vertical radiator section, high power transmission "Line Isolator©," no. 14 stranded antenna wire, and glass-filled insulators. The CAROLINA WINDOM package comes with CoaxSeal® and illustrated manual. It lists for $69.95.

For more information, or a copy of the RADIO WORKS 56 page "Discovery" catalog, call or write the RADIO WORKS, Box 6159, Portsmouth, Virginia 23703. Phone: (804)484-0140.

Circle #306 on Reader Service Card.

B-3030-G RF Amplifier

The Mirage B-3030-G is the next generation of Power Amplifiers for 144 to 148 MHz. Features include automatic shut-down circuitry for protection against high antenna VSWR, high temperature, and excessive RF power input. A GaAs-FET receive pre-amp provides high gain and low noise amplification for weak signal applications. The pre-amp includes an attenuator to reduce signal output level. Provision is made for automatic or remote (external) keying, and for remote control of all front panel functions using the Mirage/KLM RC-1 Remote Control Unit. The Mirage B-3030-G is capable of FM, SSB, and CW operational modes. Contact Mirage/KLM Communications Equipment, Inc., PO Box 1000, Morgan Hill, California 95037. Telephone (408)779-7363.

Circle #302 on Reader Service Card.

YO Yagi Optimizer Software

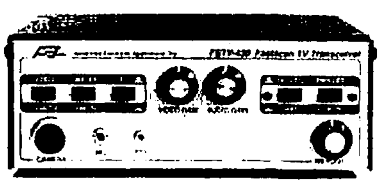
The new YO program for IBM PC and compatible computers will automatically adjust the element lengths and spacings of a Yagi-Uda design to maximize forward gain, optimize pattern, and minimize SWR. Radiation patterns at the center and edges of a band, and a scale drawing of the antenna, are plotted on CGA, EGA, or HGC graphics screens during optimization. Hard copies of the plots may be made on dot-matrix printers. YO will compute several trial designs per second for small Yagis, with a math coprocessor chip installed (not required). Yagis having up to 50 elements may be modeled. The YO design package includes models for gamma and hairpin matching networks, element tapering, mounting plates, and frequency scaling. A library of Yagi files and documentation is included. YO is $90 postpaid ($95 California and foreign), and is available from Brian Beezley, K6STI, 507-1/2 Taylor Street, Vista, California 92084.

Circle #000 on Reader Service Card.

AEA Fast-Scan TV Transceiver

AEA's new FSTV-430 fast-scan TV transceiver lets you add live color transmission to your Amateur Radio communications.

The FSTV-430 transceiver connects to the video output of a video camera so you can transmit and receive live or taped videos. A second video camera can be used for studio-like "shooting" from other angles



(continued on page 90.)

Tom McMullen, W1SL

TEST EQUIPMENT— EASY AND USEFUL

In these modern days of high-tech gadgets and equipment, we sometimes tend to forget that the test equipment we use to build, check, and maintain our Amateur stations can be quite simple. While digital readouts and touch-pad programmed meters are certainly attractive and a joy to own, there's a lot to be said for some of the basic instruments you can build. They can be extremely useful around the shack. Because they are so simple, very little can go wrong.

Here's a gadget that I've used for years to check and monitor everything from old vacuum-tube equipment (would you believe a 6L6 oscillator driving a pair of 807s?) for 80-meter CW use, to a UHF Yagi.

The meter

I've always referred to this device as "the meter," as in, "let's get the meter and check it out." "It" was whatever project I was working on at the moment. The meter is basically a microammeter mounted in a metal box along with a diode RF detector (see **Figure 1**). Almost any sensitive meter will do; a metal enclosure is recommended. The size of the box isn't important, as long as the meter and other parts will fit inside. You'll find plenty of suitable meters and enclosures at most radio flea markets, or you can go to your local Radio Shack and browse through their racks of bagged goodies.

Figure 1 shows a basic "no frills" detector and meter. A more versatile version is shown in **Figure 2**. A switch and some resistors have been added to let you change the sensitivity for different signal strengths.

Construction isn't critical, with the exception of the diode leads and the leads of the 0.001 μF capacitors. Keep these as short as practical. Don't cut the diode leads too short or you'll overheat the diode when you solder it.

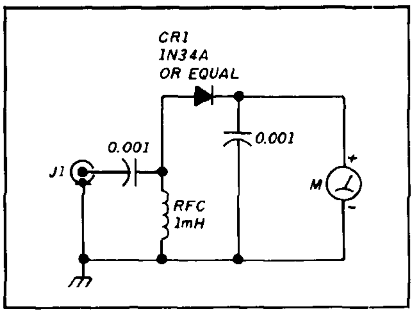
The first meter I built had an SO-239 coaxial fitting for J1. I later put in a BNC type, which made it easier to change whatever was plugged into it. Use whichever type fitting you prefer. You can use insulated stand offs or tie points to connect the capacitor, diode, and meter leads together. The capacitors can be plain disc-ceramic units with a voltage rating of 50 or higher.

The switch can be any rotary or push-button type, as long as it fits in the box you're using. If you don't have a switch with four positions, just connect resistors to whatever you have. The one shown in **Figure 2** just happened to be in my junkbox, so that's what went into the meter.

The resistors aren't critical either. The idea is to put more resistance in the circuit with each switch position. When whatever you're measuring provides a full-scale reading, switch to the next position and continue. Any value close to those shown will work.

The meter itself is critical in current capacity only, but there's a lot of room to experiment. I use a 0 to 100 μA meter obtained from a "bargain box" sale at Radio Shack. Anything from 0-50 to 0-500 μA should work okay; the physical size is your choice. I once used a 12-inch wide meter (from an old battery-charging panel) in an antenna-checking version of the meter. It had a 50-mA movement (originally used with shunt resistors and calibrated to 500 A) and a huge pointer that could be seen from several hundred feet away. Before I retired it, I used this meter to tune up several UHF antennas.

FIGURE 1



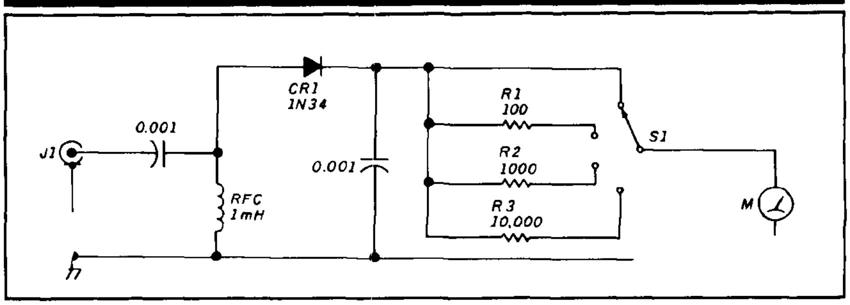
The meter is basically a microammeter with a diode detector, mounted in a metal box along with a coaxial connector.

Accessories

So far, I've discussed a basic RF detector (the diode and C1), and a meter that will display the current produced by the diode. Now, I'll look at some input devices.

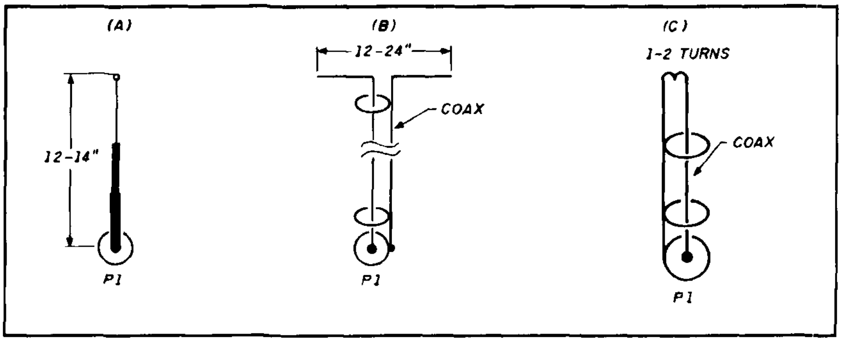
The unit that's most often connected to my meter is a telescoping antenna which is approximately 14 inches long when extended (see **Figure 3A**). You'll find them for sale at low prices at flea markets or hamfests. You can also purchase them inexpensively from Radio Shack or by mail order. Some come

FIGURE 2



Adding a selector switch and resistors to the basic meter makes the device more versatile in handling different signal strengths.

FIGURE 3



RF pickup devices for the meter. Shown at A is a simple telescoping whip mounted on a coaxial fitting. A dipole and length of coax, B, serves as a remote pick-up antenna. The two-turn loop and short piece of coax, C, is used to "sniff" out RF on power leads, house wiring, and TV antenna leads.

with a BNC fitting on the base already, but it's not hard to connect one if there's no fitting. I prefer a whip that has a swivel joint at the base — it can be tilted for best signal pickup.

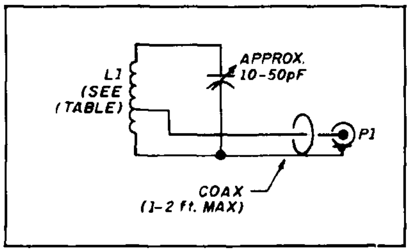
If you don't have a telescoping antenna, you can use a 12 to 14-inch length of stiff copper wire as a general RF pickup device. Any RF in the area will provide a meter reading if the field is strong enough.

A dipole antenna with a short (6 to 10 foot) length of coaxial cable between it and the BNC connector is another useful input device (**Figure 3B**). The dipole isn't critical, a 12 to 24 inch length tip to tip is fine. I used a couple of pieces of brass brazing rod stuck into a piece of plastic rod that served as a center insulator. My favorite use for this is as a very rough check of antenna radiation pattern or strength. Just tape it to a wooden pole or broom handle and stand it up several feet away from the antenna you're working on.

The next device is an RF "sniffer." It's just a 2-turn loop of no. 16 enameled wire, approximately an inch in diameter, connected to the end of a couple of feet of RG-58A/U coaxial cable, as shown in **Figure 3C**. This sniffer is very useful for finding RF that's sneaking along the outside of coaxial feedlines, house wiring, or whatever.

Figure 4 shows a device I've used to tune up many oscillator/mixer/multiplier circuits. The loop in **Figure 3C** will pick up RF from a tuned circuit, but won't tell you the frequency. The tuned circuit in **Figure 4** will. It's a "wavemeter" device that you can place near a circuit that contains RF energy. As the wavemeter is tuned to the frequency of the RF in an oscillator, for example, the meter will show a reading. Admittedly, it's not as accurate as a frequency counter, but I've found it very useful in determining quickly that a crystal oscillator wasn't working on the correct overtone, that a doubler circuit was really tripling, that the output of a mixer was F1+F2 instead of F1−F2, and so on.

FIGURE 4



A tuned circuit can act as a wavemeter when connected to the meter via a short length of coax. See *Table 1* for some suggested values of L1, or look in the theory section of most Amateur Radio handbooks for ideas on other combinations and frequency ranges. C1 can be any small variable capacitor with a range of approximately 10 to 50 or 10 to 75 pF. The coil form can be mounted on a long screw or a stand-off insulator for support.

Wavemeter calibration

Calibrating a wavemeter like this one may be puzzling to some. It's not hard to do. Visit a friend who has a multiband transmitter and put the coil near the antenna (keep the transmitter on low power, of course). Vary the capacitor for a maximum reading. By marking the position of the knob for the frequencies you find, you can make a good estimate of any that fall between Amateur bands. Most dip meters will produce enough RF to cause a small meter indication when tuned in, and you can use this method to make a useful calibrated scale.

Another method involves connecting the tuned circuit in parallel with your receiver antenna input. Just put a "T" fitting in the coax near your receiver input jack, connect the tuned circuit to one leg of the T, and listen to a signal as you tune the capacitor. When the circuit is resonant at the signal's frequency, the signal will decrease markedly, and may even disappear. A general-coverage receiver will provide many calibration points; a ham-bands only rig will give you several frequencies at important parts of the range.

I hope you'll find the meter as useful as I have. Many times, it's the first thing I grab to look at the basics of what's happening in a circuit or antenna. At one time, when my residence was in the midst of acres of trees instead of a housing development, I had the little dipole mounted on a 20-foot wood pole at the end of

TABLE 1

Table 1. Suggested coil data for the wavemeter attachment. The frequencies listed are approximate. You can tailor them to your needs by adding or removing turns.

Frequency, MHz	Turns	Tap	Wire Size
3.5 to 8	35	11	No. 30 enameled
7 to 15	22	8	No. 20 enameled
14 to 30	10	3	No. 20 enameled
30 to 100	4	1	No. 20 enameled
75 to 200	hairpin, 1/2" wide, 2" long, tap 1" from ground. No. 14 enameled or bare wire.		

All coils except the hairpin can be wound on a 1" diameter plastic form for support. Windings are close to each other except for the 30 to 100-MHz range, which is spaced to be approximately 1" long.

500 feet of surplus coaxial cable. Because it was located exactly north of my 2-meter beam antenna, I always had a way to check antenna-rotator position and relative beam-antenna performance.

Precautions

As much as I miss the "good ole days" and their simplicity of life, there are other things that I'm glad to have learned. For example, I no longer work on antennas with 5, 10, or 20 watts of power being fed to them. When I do "tweak" an antenna with power being fed to it, the power is limited to a few milliwatts. Even then, I stay away from the front of any directive beam like a dish reflector or large Yagi. (I don't know how much RF is harmful, but why push my luck!)

Another "gotcha" is the pick-up antenna — especially the dipole. Don't leave it connected to the meter when you're not using it to measure or check something. It's nice to have a constant monitor of how your antenna is radiating or how your transmitter is putting out, but that diode in the box is a great harmonic generator. Where are the harmonics going to go? Right back up the coax and out of the antenna to your neighbor's TV set, of course. To avoid problems, disconnect the whip or dipole from the meter unless you're actually checking something. The sniffer loop and the tuned circuit will pick up RF fields at several inches from most transmitter tuned circuits, and most transistorized circuits don't have more than 10 or 12 volts of DC that you can contact. However, for vacuum-tube final amplifier stages and some high-powered solid-state circuits, caution is the important word. Not only is the DC in a plate circuit bad for your health, but the RF will cause severe burns if you get careless. However, with a sensitive device like the meter, you'll be able to pick up enough RF for an indication long before you get close to the danger point. You can even locate some RF leaking out of metal enclosures on most high-powered amplifiers. It's surprising what you can find out about shielding and bypassing with the sniffer loop.

In my next column, I'll look at an RF output measuring device that you can connect to your transmitter or use as a test instrument. Some of you may have seen one before, but I'll refresh your memory and show everyone else how easy it is to build. hr

(continued from page 84)

If you own a video camera, you can set up an ATV station by adding a FSTV-430 transceiver and a 430-MHz antenna like AEA's 430-16. You only need a Technician or higher Amateur Radio license.

The FSTV-430 available from AEA authorized dealers. The suggested retail price is $499.95.

For more information contact AEA, P.O. Box C-2160, Lynnwood, Washington 98036, telephone (206)775-7373.

Circle #309 on Reader Service Card.

IC-901 Fiber Optic Multi-Band Transceiver

ICOM has introduced the IC-901 Fiber Optic Remote Mount Multi-Band Transceiver.

• ICOM's IC-901 comes standard as a dual band FM transceiver (2 meter and 440 MHz). Users can add band units to complete their system. The following band units from the IC-900 can be installed on the new IC-901.

UX-19A 10 meter 10 watt
UX-39A 220 MHz 25 watt
UX-59A 6 meter 10 watt
UX-129A 1.2 GHz 10 watt

Other optional band units will include the UX-S92 144 MHz SSB Module that will allow for USB, LSB, and CW operation.

- The band units and interface box can be installed in a car trunk and the control head can be mounted on the dash via fiber optic cable. The control head can be installed directly to the interface box for a compact transceiver, or it can be connected to the interface box via the control cable.
- Other features include a multicolor LCD that displays squelch and volume settings and an HM14 touch tone microphone.
- The IC-901 also has DTMF ANI. The operator can set a code and give it out selectively. When the transceiver receives a signal preceded by this code, squelch will automatically open for the transmission — no other noise will be heard.

For more information, please contact ICOM at (206)454-8155 or write ICOM America, Inc., PO Box C-90029, 2380 116th Avenue NE, Bellevue, Washington, 98009-9029.

Circle #301 on Reader Service Card.

Programmable Miniature Two-tone Sequential Encoder

Communications Specialists, Inc. offers a new PE-2P DIP switch programmable Two-tone Sequential Encoder. The PE-2P is designed to be mounted inside a radio or other housing, and lets you send a single two-tone sequential paging call. The PE-2P has standard 1 second—3 second timing. It's compatible with Communications Specialists SD-1000 Two-tone Decoder and other systems like the Motorola Quick-Call II, 1+1, and GE Type 99. The timing may be changed to match other two-tone formats.

Both tone A and tone B are DIP switch programmed from a 32 tone memory base that is specified when ordering. This allows over 1000 possible combinations from a single PE-2P. With some additional circuitry, the PE-2P may be wired to send multiple calls.

The PE-2P measures 1.25" x 2" x 0.4" to allow installation into most mobile radios and is powered by +10 to 16 volts DC. The selected call is activated by a momentary ground. A 150-mA output is provided to key PTT.

The PE-2P is priced at $54.95. Communications Specialists' standard one year warranty applies.

For more information, contact: Communications Specialists, Inc. 426 West Taft Avenue, Orange, California 92665-4296. Telephone (800)854-0547 or (714)998-3021 (local). FAX (714)974-3420.

Circle #312 on Reader Service Card.

Warranty Expansion to Cover Lightning Damage

Advanced Computer Controls, Inc. has expanded its two-year warranty for the RC-96 Repeater Controller to cover lightning damage.

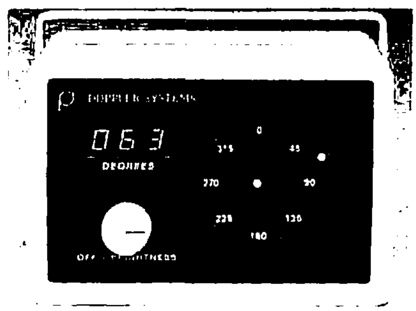
ACC manufactures microcomputer-based control systems for Amateur, commercial and government radio users. For additional information, contact Advanced Computer Controls, Inc., 2356 Walsh Avenue, Santa Clara, California 95051. Phone (408)727-3330.

Circle #311 on Reader Service Card.

New Expanded Line of Radio Direction Finding Systems

Doppler Systems offers an expanded line of radio direction finding systems covering frequencies up to 1 GHz. The new 5000 series provides improved accuracy as well as a wider frequency range using a remote RF summing circuit. Typical accuracy is ±5 degrees. A wide range of antennas is offered to cover frequencies between 108 and 1000 MHz.

There are four processor/display models. DDF5001 displays the bearing with 16 high intensity LEDs arranged in a circle. The DDF5002 has a three-digit display for 1 degree resolution. Models DDF5003 and 5004 provide an RS232 serial interface and synthesized speech. The RF summer DDF5050 is available in a variety of cable lengths for mast mounting. The mobile version is DDF5060.

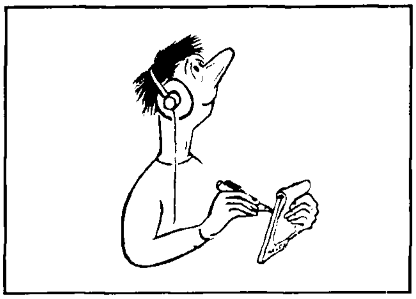


Mast-mounted antennas include frame-mounted dipoles DDF5051 and 5052 for coverage of the 108 to 136-MHz and 136 to 180-MHz bands. Monopole antennas with groundplanes are used for 350 to 500 MHz (DDF5055) and 700 to 1000 MHz (DDF5057). Magnetic-mounted mobile antennas are also available. DDF5061 covers 108 to 136 MHz, and DDF5062 spans the 136 to 500-MHz range. Frequencies between 700 and 1000 MHz are covered with the DDF5067.

For further information, contact Doppler Systems Inc., PO Box 31819, Phoenix, Arizona 85046. Telephone (602)488-9755. FAX (602)488-1295.

Circle #310 on Reader Service Card.

DX Forecaster



Garth Stonehocker, KØRYW

MORE ON EQUINOX PROPAGATION

Last month's discussion of equinoctial propagation, changing daylight conditions, and solar initiated events is also pertinent to October because the equinox occurs late in September. The spring of 1989 gave us an example of events during a typical equinox (though actually they may have been worse than usual). This month I'd like to consider these geophysical events and their signal strengths and midlatitude day and night ionospheric usable frequency changes affecting propagation.

The small geomagnetic disturbances on March 3rd and 5th decreased the daytime ionospheric density vertical reflections by 11 and 18 percent, respectively. They decreased by twice that at night. The big solar flare on the 10th at 1922 UTC induced a sudden ionospheric disturbance (SID) which had maximum D region signal absorption affecting propagating signals at the equator below the central United States (Denver), and then had stronger signals east to 30 degrees and west to Samoa. During the flare (related to flux burst and shape intensity), the amount of signal loss and its length (maximum of several hours) depend on frequency.[1] The polar cap signal absorption (PCA) started soon after, affecting polar path signals during daylight hours for three days. Meanwhile, the geomagnetic disturbance started on the 12th. The disturbance increased the midlatitude ionosphere by 15 percent initially, then decreased it on the 13th by 65 percent. The ionosphere recovered to median values by the 17th. Signals were gone completely on most midlatitude and higher paths for most of the 14th, and then very QSB while recovering.

The next large flare on the 23rd at 1959 caused a large, but not as lengthy, SID in the same area as the one on the 10th. The PCA lasted 12 hours on polar paths. The geomagnetic disturbance began on the 27th at 1342 UTC, decreasing the ionospheric density 19 percent. The disturbance continued until April 5th and kept the ionosphere down from 14 to 47 percent, the latter percentage occurring on March 31st.

In April, the first large solar flare and its accompanying flux burst took place on the 9th at 0105 UTC. A large SID, which lasted over an hour with its maximum D region signal absorption (sub solar point), was on the equator above New Zealand. It covered the region from India to Denver with signals of increasing strength in directions away from the subsolar point. No geomagnetic-ionospheric disturbances of importance resulted from this flare. The next flare was on April 23rd at 2155 UTC. No SID was reported, even though this was an x-ray flare of over an hour's duration. Its maximum effect should have been on the equator south of Hawaii, extending across the United States to the east and Australia to the west. A geomagnetically disturbed ionosphere started on the 25th at 1859 UTC with a drop in electron density of 25 percent which decreased the next day, but continued off and on until the 29th around 1000 UTC. This is representative of a "typical" propagation summary through a spring equinox season near sunspot cycle maximum.

Last-minute forecast

The first two weeks of the month are expected to have a high solar flux producing increased MUFs. However, these MUFs should be above our 10-meter band. The hours of openings should be longer, but the signal strengths will fall on the 10 to 30-meter bands. Look for good transequatorial openings to be more plentiful in the late evenings. In particular, look for enhancement around the 4th, 12th, and 21st because of a higher probability of geomagnetic-ionospheric disturbance. The lower bands, usually better for night-time DX, should be good the 2nd and 3rd weeks of the month. During the disturbed periods, look for unusual DX locations to be heard in the weak and fluttery signals to the east and west.

The Orionids meteor shower will be visible from the 15th to 24th of October, with a maximum rate of between 10 and 20 per hour on the 20th to 21st of the month. The moon is full on the 14th, and perigee occurs on the 15th.

Band-by-band summary

Ten, 12, 15, 17, and 20 meters will be open from morning to early evening almost every day to most areas of the world. The openings on the higher of these bands will be shorter and occur closer to local noon. Transequatorial propagation on these bands will most likely occur toward evening during conditions of higher solar flux and a disturbed geomagnetic field.

Thirty and 40 meters will be poor during the day. Nighttime DX will be good, except after days of high MUF conditions and geomagnetic disturbances. Look for DX from unusual places on eastern, northern, and western paths during this time. The usable distance is expected to be somewhat less than that on 20 meters in daytime and greater than that on 80 meters at night.

Eighty and 160 meters will be opening for DX at dusk. These bands follow the darkness path, opening to the east just before your sunset, swinging more to the south near midnight, and ending up in the Pacific areas during the hour or so before dawn. The 160-meter band opens later and ends earlier than 80.

REFERENCES

1. Bill Orr, W6SAI, "Ham Radio Techniques: Have You Met SID," *Ham Radio Magazine*, page 31.

OCTOBER

WESTERN USA

GMT	PDT	N (ASIA FAR EAST)	NE (EUROPE)	E (S. AFRICA)	SE (S. AMERICA)	S (ANTARCTICA)	SW (NEW ZEALAND)	W (OCEANIA AUSTRALIA)	NW (JAPAN)
0000	5:00	12	30	12	10	10	10	10	10
0100	6:00	12	30	15	10	10	10	10	12
0200	7:00	15	30	15	10	10	10	10	12
0300	8:00	17	30	17	10	10	10	10	15
0400	9:00	20	30	30	12	10	10	10	20
0500	10:00	20	30	17	12	10	10	10	20
0600	11:00	30	30	17	15	12	12	12	20
0700	12:00	30	30	17	15	15	12	12	30
0800	1:00	30	30	17	15	17	15	15	30
0900	2:00	30	30	30	17	17	15	15	30
1000	3:00	30	30	30	17	17	15	15	30
1100	4:00	30	30	30	17	20	17	15	30
1200	5:00	30	20	10	17	20	17	17	30
1300	6:00	30	15	10	10	20	17	17	30
1400	7:00	20	15	10	10	15	17	17	30
1500	8:00	30	12	10	10	10	17	17	30
1600	9:00	30	12	10	10	10	17	12	30
1700	10:00	30	15	10	10	10	12	12	30
1800	11:00	30	15	10	10	10	12	15	30
1900	12:00	30	17	10	10	10	10	12	17
2000	1:00	30	20	10	10	10	10	12	12
2100	2:00	30	20	10	10	10	10	10	12
2200	3:00	30	30	10	10	10	10	10	10
2300	4:00	17	30	10	10	10	10	10	10

MID USA

MDT	N (ASIA FAR EAST)	NE (EUROPE)	E (S. AFRICA)	SE (S. AMERICA)	S (ANTARCTICA)	SW (NEW ZEALAND)	W (OCEANIA AUSTRALIA)	NW (JAPAN)	CDT
6:00	12	30	12	10	10	10	10	12	7:00
7:00	15	30	15	10	10	10	10	15	8:00
8:00	17	30	15	10	10	10	10	15	9:00
9:00	20	30	15	10	10	10	10	20	10:00
10:00	20	30	17	12	10	12	12	20	11:00
11:00	30	30	30	12	12	12	12	20	12:00
12:00	30	30	30	15	15	15	15	30	1:00
1:00	30	30	30	15	15	15	15	30	2:00
2:00	30	30	30	17	17	17	15	30	3:00
3:00	30	30	20	17	17	17	17	30	4:00
4:00	30	20	17	17	20	17	17	30	5:00
5:00	30	17	15	15	20	17	17	30	6:00
6:00	20	15	10	12	20	17	17	30	7:00
7:00	30	15	10	10	15	17	17	30	8:00
8:00	30	12	10	10	12	15	17	30	9:00
9:00	30	12	10	10	10	12	12	30	10:00
10:00	30	12	10	10	10	17	15	30	11:00
11:00	30	15	10	10	10	12	17	30	12:00
12:00	30	15	10	10	10	12	12	17	1:00
1:00	30	17	10	10	10	10	12	15	2:00
2:00	30	20	10	10	10	10	12	12	3:00
3:00	30	20	10	10	10	10	10	12	4:00
4:00	30	30	10	10	10	10	10	12	5:00
5:00	17	30	10	10	10	10	10	10	6:00

EASTERN USA

EDT	N (ASIA FAR EAST)	NE (EUROPE)	E (S. AFRICA)	SE (CARIBBEAN S. AMERICA)	S (ANTARCTICA)	SW (NEW ZEALAND)	W (OCEANIA AUSTRALIA)	NW (JAPAN)
8:00	30	30	12	10	10	10	10	20
9:00	30	30	15	10	10	12	12	20
10:00	30	30	15	10	10	12	12	20
11:00	30	30	15	12	10	15	15	30
12:00	30	30	20	12	12	15	15	30
1:00	30	30	17	15	15	15	15	30
2:00	30	30	17	15	15	17	17	30
3:00	30	30	17	15	17	17	17	30
4:00	30	30	17	17	20	17	17	30
5:00	30	17	15	17	20	17	17	30
6:00	17	15	10	15	20	17	17	30
7:00	15	15	10	12	17	17	17	30
8:00	12	15	10	10	15	15	12	30
9:00	17	12	10	10	12	15	12	30
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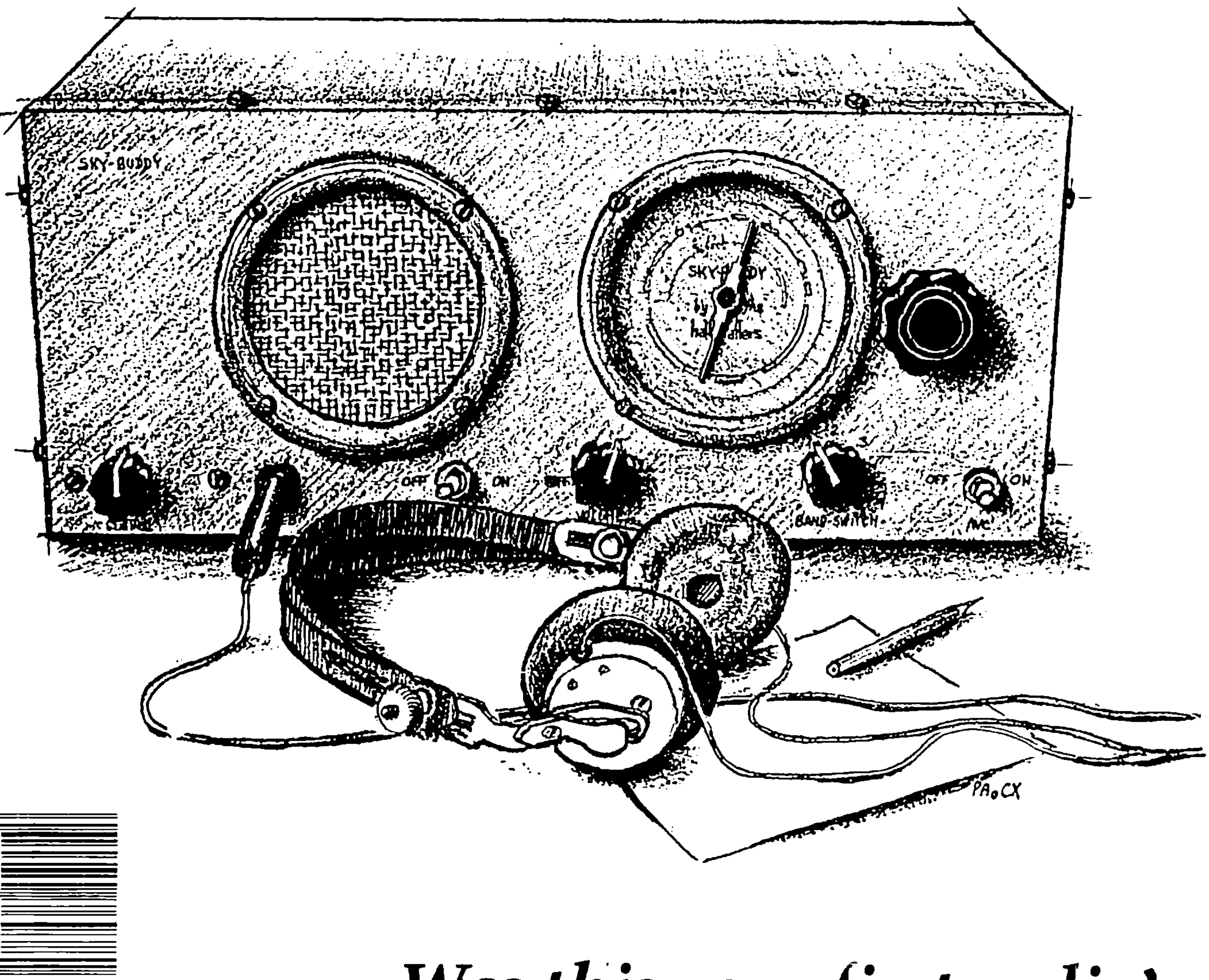
11:00	20	12	10	10	10	17	15	30
12:00	30	12	10	10	10	12	15	30
1:00	30	15	10	10	10	12	17	30
2:00	30	15	10	10	10	10	12	30
3:00	30	17	10	10	10	10	12	20
4:00	30	20	10	10	10	10	10	15
5:00	30	30	10	10	10	10	10	12
6:00	30	30	10	10	10	10	10	12
7:00	30	30	12	10	10	10	10	12

NOVEMBER 1989 / $2.95

Annual Receiver Issue

NEW HAM RADIO

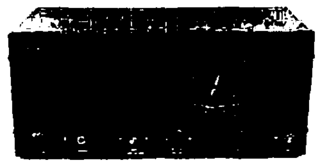


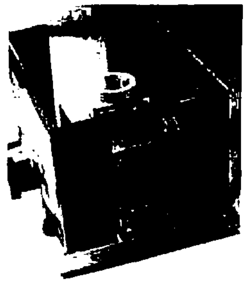
Was this your first radio?

HAM RADIO

NOVEMBER 1989
Volume 22, Number 11

Cover Illustration: Hans Evers, PA0CX


K4KJ, page 43


VE3RF, page 62

FEATURES

DEPARTMENTS

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Backscatter

A Juxtaposition of Technologies

It's fun to take a look back at the past from time to time to see how technology has changed. Last month we previewed Kenwood's new state-of-the-art HF transceiver, the TS-950S. The TS-950S offers the latest in digital signal processing (DSP) technology and ergonomically designed operator features.

This month John Nagel, K4KJ, takes us back to the early thirties with a retrospective piece on the Sky Buddy and several other Hallicrafters radios of that era. This remarkable juxtaposition of technologies serves to show us how much the science of communication has changed in the fifty or so years since the Sky Buddy was first manufactured. Communications technology has made great strides forward since then. We take these changes for granted, however, and have lost touch with exactly how much radio has changed.

Recently, a newly licensed Novice stopped by to see me. He was looking for some help in getting on the air. He already had a receiver and had just been given a Heathkit DX-35 transmitter. He was flummoxed by the transmitter; he had no idea how to peak a grid, tune and dip the final. He was also missing some crystals (Crystals? Who uses those archaic things?) and was having no luck finding any. Luckily, I had mine from twenty-plus years ago squirreled away and was able to get him set up for 15 and 80 meters.

As we sat watching the unit warm up, I was taken back to *my* Novice days and remembered fondly how much fun I had in that one year as WN1IGG. After I showed him how to peak the grid and dip the final, he went home to finish setting up his station. I'll give him a call in a few days to see how he's doing. Frankly, I had forgotten how complex station set up could be. Like most of the rest of us, I've been spoiled by the features and convenience of today's transceivers. I'd also forgotten the limits of a crystal-controlled transmitter. Split frequency operation was normal back when I started in radio. Sometimes the station you were working was half the Novice band away. I had only three crystals for the 15-meter Novice band, so I spent many hours either scanning the band looking for someone close by or calling hopefully to someone 5 or 10 kHz (or more) away. Those were fun days.

WARC bands

I recently put up an antenna for 18 and 24 MHz. Gary Nichols, KD9SV, sent me a prototype of a trap dipole he's designed. (The antenna will be featured in an *HR* article early next spring.)

The antenna is very light and installs in almost any location. As I tuned across the 18 and 24 MHz bands, I was amazed at the quality of propagation. I'll be the first to admit that I made no rush to get on any of the WARC bands when they were first authorized. However, I'm beginning to think I made a mistake. I've found a number of my low band cronies there; they've been extolling the virtues of 18 and 24 MHz to me for months. Well, they were right; 18 and 24 MHz are two fun bands. There's plenty of DX to be worked from every corner of the earth. I hope you haven't waited as long as I have to get on. While activity is spotty now, these bands will sound like 15 or 20 meters as more hams find out how good 18 and 24 MHz can be! Imagine, wall-to-wall DX. See you there.

Craig Clark, NX1G

Editor's Notes

It's been just over a year since the "New" *Ham Radio* was introduced and your response has been tremendous. More and more Amateurs are reading *Ham Radio* Magazine.

When we began this new phase in *Ham Radio's* history, our intentions were to apply the high technical standards you expect from *Ham Radio* to the kinds of articles you're interested in *right now*. Recent reader surveys and evaluation cards indicated you had a desire for more short construction articles, practical projects, and weekenders, along with both brief and in-depth technical pieces that have long been a mainstay of the magazine. We've listened to your requests and have spent the last fourteen months working with our authors to bring you just what you've asked for.

This past year has been a good one — so let's keep the momentum going. I'd like to ask those of you who have played a part in shaping *Ham Radio's* new focus to continue sending us the articles your fellow readers have asked to see. I'd also like to urge those of you who haven't yet shared your pet projects with your peers to take this opportunity to become a *Ham Radio* author. We pay well and make every attempt to get your efforts into print as soon as possible. *HR* uses up a lot of material in a year's time, so we need your help to keep our pages both full and interesting. Let us help you share your ideas with an international audience!

Terry Northup, KA1STC

Comments

WE CAN MAKE A DIFFERENCE

There has been a lot of talk about how slowly ham radio is growing and the need for new Amateurs. The talk usually centers on code versus no code, or club activities to recruit new hams. Hams are also urged to get the message out by various PR efforts.

It seems to me that there is a tendency to allow groups or organizations to do the work (i.e., ARRL or clubs) without accepting the responsibility ourselves. At the same time, I hasten to say that such efforts from the ARRL and clubs do have merit — it is just that in the process individual hams do little or nothing.

What I propose is that each one of us recruit just one ham to the ranks of Amateur Radio. Lets see: 400,000 hams x 2 =!

Bruce Bennett, K2PDJ,
Alexandria Bay, New York

CHALLENGING YOUTH

Dear HR

The letter by Paul Swearington, W9PJF, (July 89) also expressed my thoughts on why we don't have more people interested in Amateur Radio. I became interested when I saw an article in the old *Pilot* radio magazine. It was on a transmitter using a UV45 tube in a tuned plate tuned grid circuit for use on the ham bands. As a result, the bug bit me. I had to get my license and so I started learning the code. The challenge was learning the code and building a transmitter.

Many of us started on 80 CW, but the challenge was to get on fone. The 75-meter band was restricted to class A hams so 160 was the band we went to. It was a fairly easy step to add a moduator to the CW rig and change a few coils. Most of the rigs were crystal controlled and most were homebrew. Today the step from CW to fone is virtually impossible if you want to have the present state of art, unless you buy a transceiver. The only challenge here might be in raising the money, but after that what? Learning all the knobs and bells can keep them going for awhile, but are they really gaining any real technical knowledge. It is alright for the oldtimers to go this route but it is the younger generation that will be the designers of tomorrow. We need this group to keep this country ahead in electronics and what better learning ground than ham radio.

I would venture to say that most Novices want to get on fone after spending some time on CW. The Novice expansions for fone or no-code license do nothing to improve their technical qualifications if they have to go out and buy a commercially built rig.

I would like to see the 160 band opened up to the Novice and Technician. It would be a band that they could get on fone, albeit on AM. But at least it would feasible for them to construct receivers and transmitters for this band without having an engineering degree. With the experience and the challenge of building their own equipment, many will go on to build better and more refined equipment. But they need a stepping stone to get there.

I have operated 160 for many years. Before World War II this band was heavily occupied and you could make a contact at almost any time of day or night. Today you may hear a few stations in the evening but they generally are on a net. There is plenty of room and plenty of challenges from homebrew transmitters and receivers to antennas. Or could it be that our younger generation doesn't like challenges?

Jim Pepper, W6QIF,
Orinda, California

A young Amateur speaks out

Dear HR

I am a member of the West Branch Amateur Radio Club (Williamsport, Pennsylvania). Our club just recently had its first "discussion" on the "no-code" topic. It was the second meeting I had been to and, being 15 years old, I saw actions that did not please me. The words became heated, and from everything I heard, I gathered that "no-code" is supposed to bring more people into our hobby. Some of our club members mentioned that they knew some "brilliant" people who would be interested in radio, if not for the code. If they are so brilliant, why can't they do the 5 wpm that a 5 year old child can do? Instead of arguing about whether there should be a code free license, let's get off our "butts" and do some advertising! Get the local club to make some signs, announcements on fm radio, arrange a showing of the ARRL promo tape. Most of all, work on the school system. Our hobby is being dominated by adults. We need the kids! Forget about your opinions and like John Muhr, KT0F, said in the August issue, "Get out there and wave the Amateur Radio banner!"

Nate Meredith, KA3TZJ,
Jersey Shore, Pennsylvania

(continued on page 90)

WIDEBAND FREQUENCY ANALYZER

Analyzer checks for spurious oscillations and amplitudes, and assists in tuning

By Adelbert Kelley, AA4FB, 2307 S. Clark Avenue, Tampa, Florida 33629

As a result of interest generated by articles I'd read in *QST*[1] and *Ham Radio*,[2] I decided to build the wideband frequency analyzer shown in **Figure 1**. I needed a test instrument that would show spurs and relative signal amplitudes, and would help me with alignment when I experimented with VHF and UHF circuits. The idea of using the shop oscilloscope for a panoramic display of the signals from 20 to 400 MHz looked attractive. K2BLA's analyzer in *QST* had an ingenious circuit which gave the frequency on a digital display. He used the scaler output of a cable TV converter in a frequency counter that subtracted the oscillator offset, then counted and presented a three-digit readout of the frequency of any signal present at the center graticule in the oscilloscope display. He measured unknowns by tuning the analyzer until the signal crossed the center line.

You can use my analyzer to check circuits for spurious oscillations and amplitude, and assist in tuning. It needn't be tuned precisely to display a signal, doesn't require close coupling, and has a wider frequency range than a grid dip meter.

My unit has the following specifications:

- Frequency coverage of 54 to 900 MHz in two bands with no gaps in coverage.
- A digital readout which displays the frequency of the center graticule of the oscilloscope to + or − 1 digit. It continues to give a useful reading even when the frequency sweep is reduced to zero and only the manual tuning knob is used.
- Two steps of selectivity, good sensitivity, and uniform frequency response. It will display all the FM, TV, Amateur VHF/UHF, and communications services in a metropolitan area when connected to a TV antenna or even a random wire.
- FM audio monitoring to identify unknown stations, and a simple design with parts count at a minimum consistant with good results.

Of course this isn't a spectrum analyzer. As a homebrewer, I don't have the resources to produce a true spectrum analyzer. The unit only approximates a logarithmic amplitude response, which is good enough for me. I use a decade attenuator[3,4]* to read relative dB amplitudes when I need more accuracy. The voltage versus frequency response of varactor diodes in cable and TV tuners is inherently nonlinear. This matters only if you want to read the frequency off the graticule of the scope. A better method is to rotate the fine tuning until the signal in question is at the center of the graticule, and read out the frequency on the digital display.

TV tuners have been evolving away from switched inductor and capacitor to solid-state varactor tuning. The varactor tuner uses the capacitance change across a silicon diode that takes place when a reverse DC voltage is varied. The capacitance increases as this control voltage is lowered. If a sawtooth waveform of sufficient amplitude and correct average DC is substituted for this DC control voltage, the tuner tunes its frequency range rapidly, and very little circuitry is needed to obtain a panoramic display. The combination of solid state and no moving parts means greater reliability, smaller assemblies, and easy interfacing. This, in turn, results in low cost and high performance.

Tuner construction details

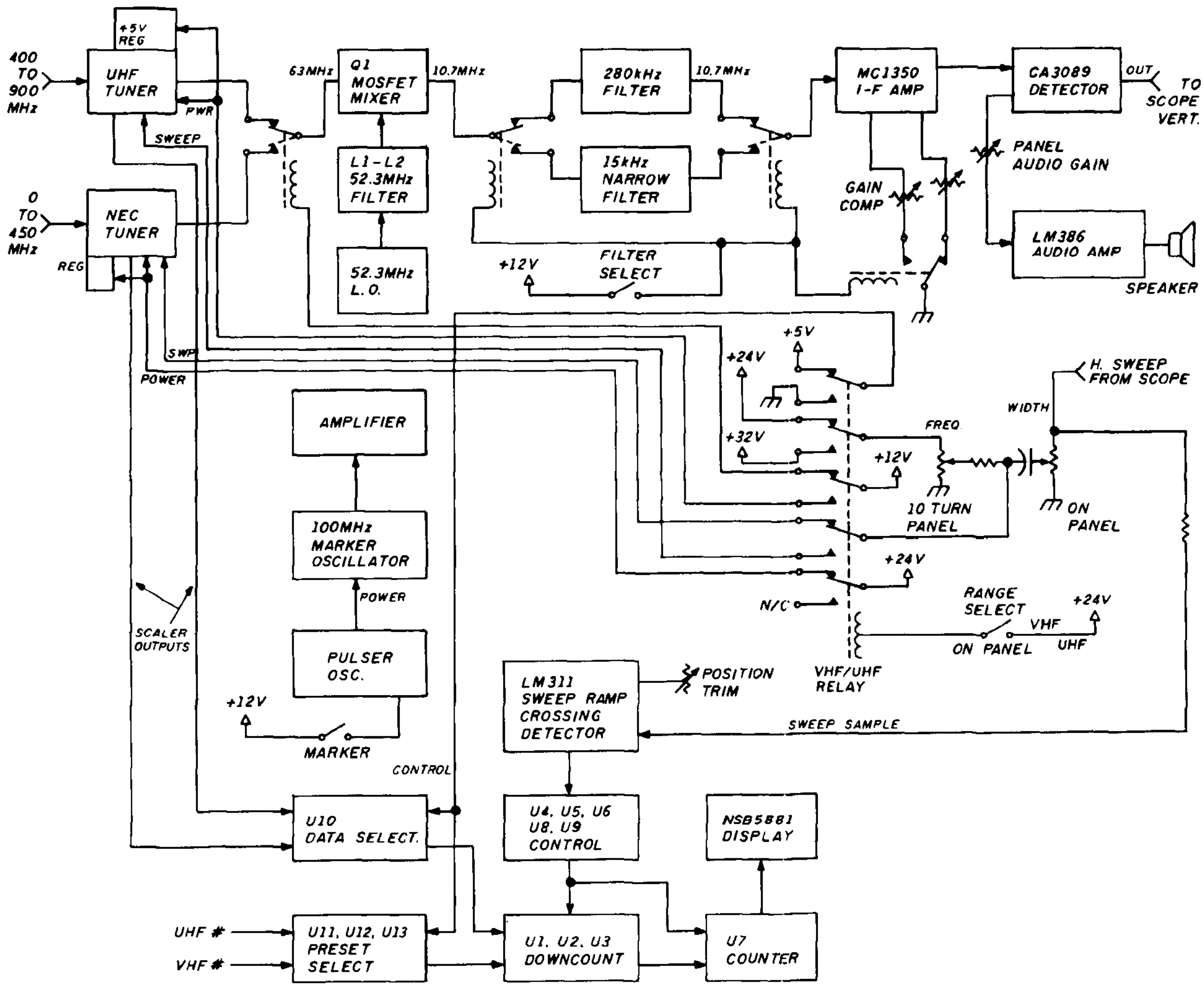
The NEC cable tuner requires no modifications. It's well shielded and appears to have a good frequency response. The 53-channel display was almost flat when I checked our local cable system on the completed analyzer.

I wanted higher frequency coverage than 400 or 450 MHz and had a UHF tuner left over from a previous project,[5,6] so I decided to try it. However, UHF tuners don't have built-in scalers. I solved this problem by adding an RCA CA3179E chip to the tuner in a circuit that should also be easy to add to any make of solid-state tuner.

Most UHF TV tuners cover channels 14 through 88 only, but the Mitsumi covers more — 500 MHz, actually. It's worthwhile to try to find one. Look for a UES-A55F or UES-A56F. Radio Shack sold one (stock no. 277-220) in 1983, but I

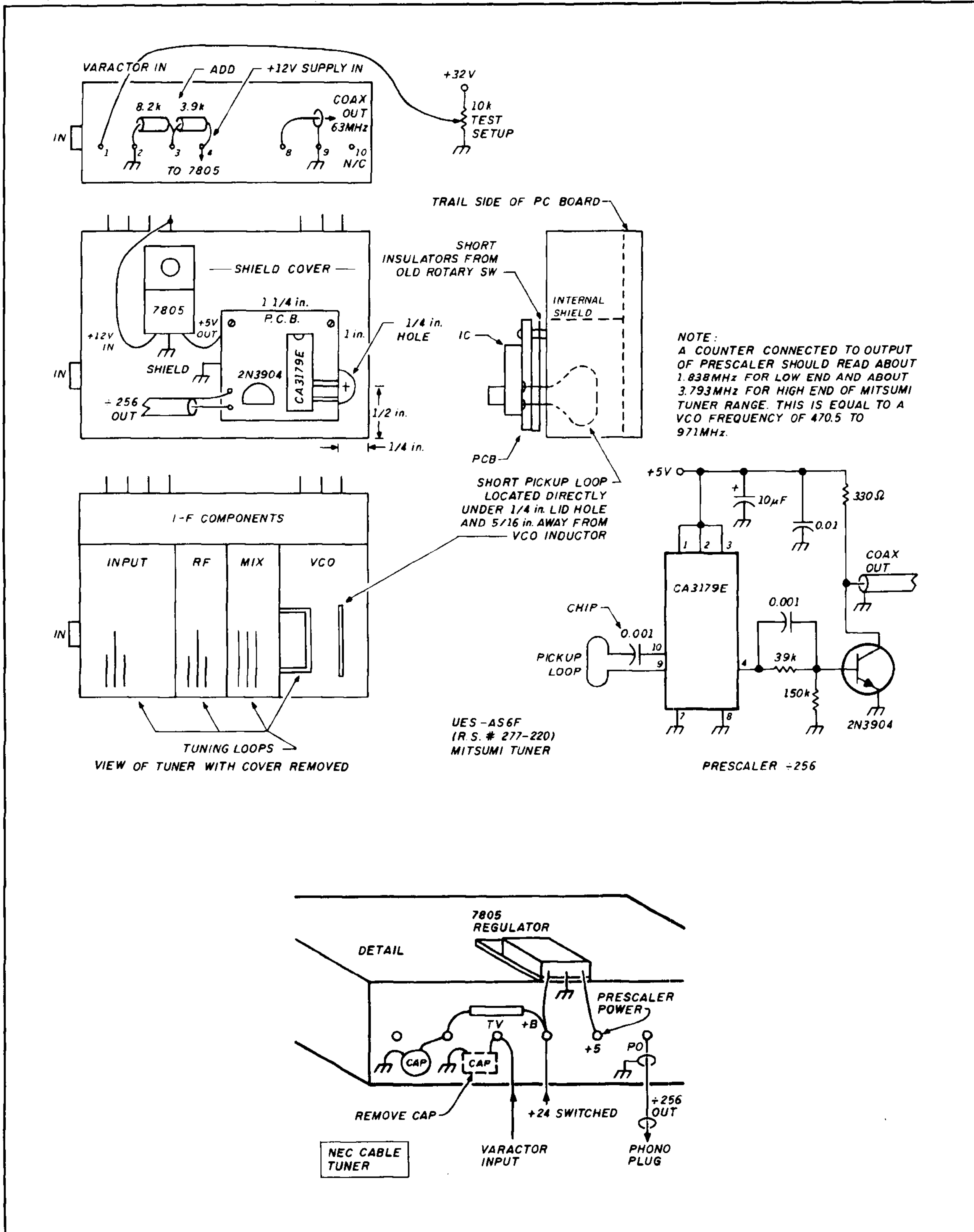
* Available as a kit from Circuit Board Specialists, (303)542 4525.

FIGURE 1



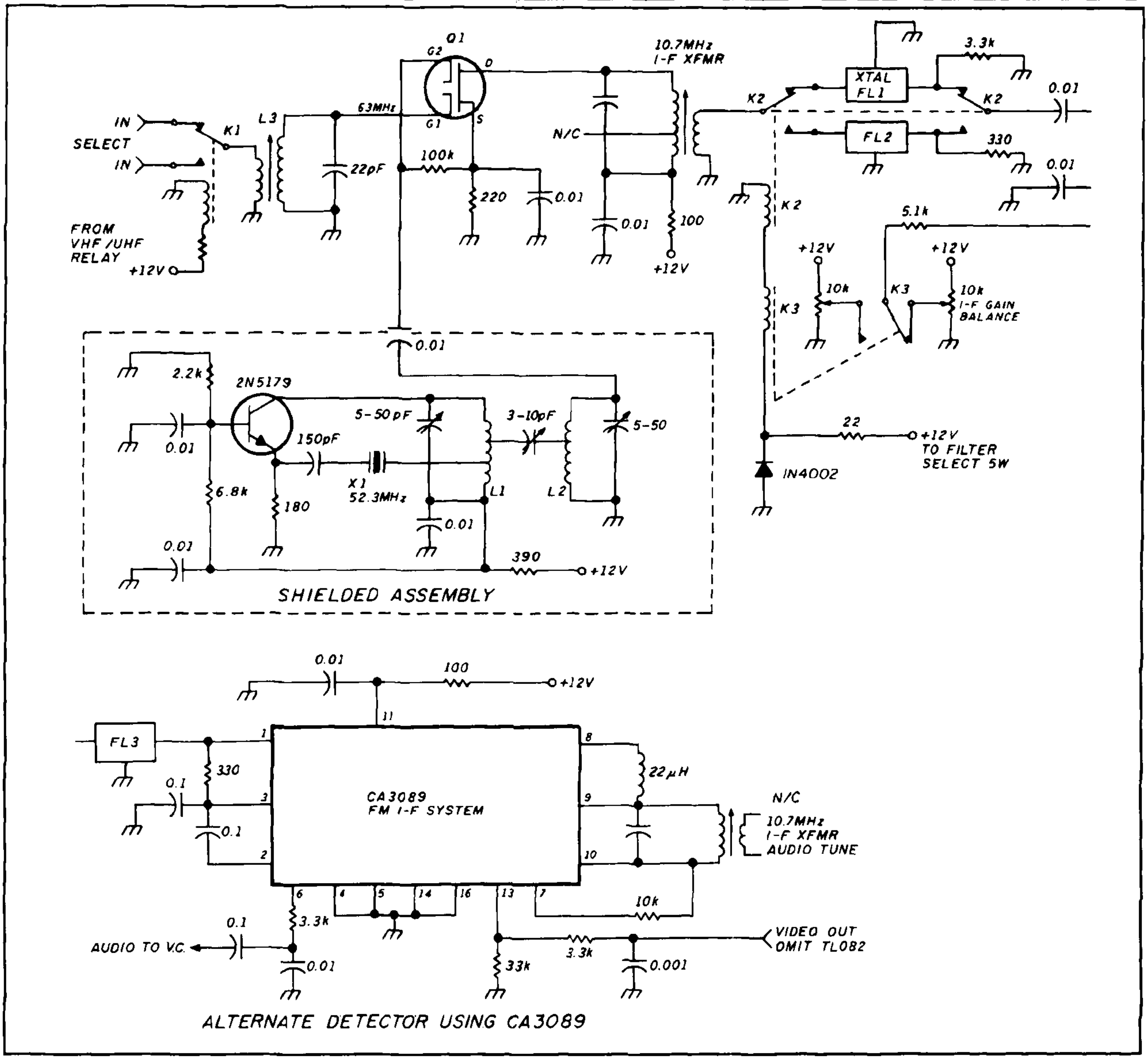
One line diagram frequency analyzer.

FIGURE 2



Mitsumi tuner prescaler installation detail.

FIGURE 3



Spectrum analyzer 10.7-MHz IF assembly.

haven't seen any recently. If you can't locate a Mitsumi, use any available tuner and settle for its top frequency. Modifications covered in **Reference 5** outline how to wind a simple transformer on a ferrite bead so you can use the tuner at 63-MHz output. There's also information on how to modify the input so it's unbalanced and shielded. This is easy to do. Many tuners are already fitted for unbalanced input. Use phono plugs and jacks and miniature coax for connections and signal routing. This Mitsumi tuner was designed for an IF output of 44 MHz, and operates well at 63 MHz — the same as the cable tuner

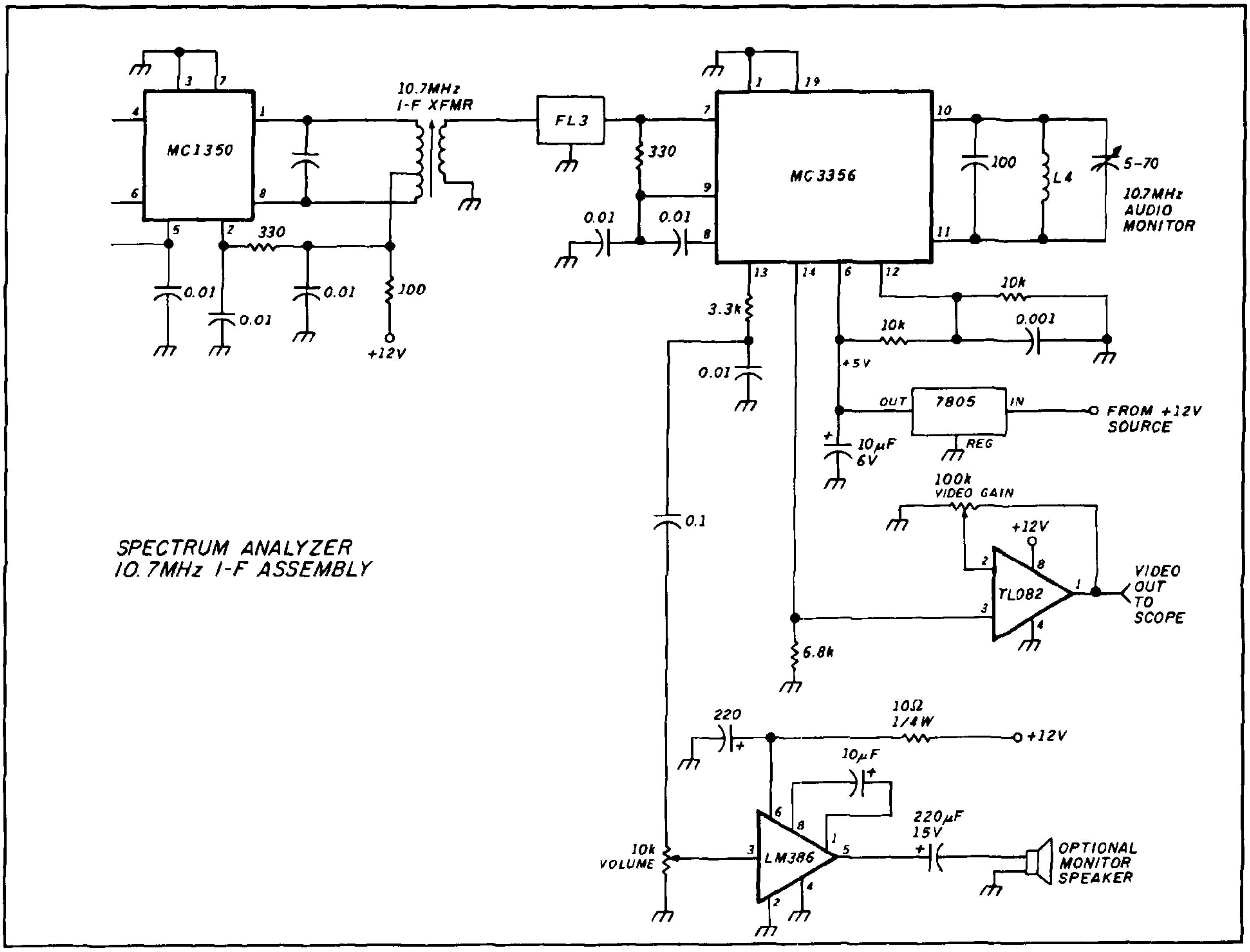
Figure 2 gives details of the prescaler installation. I mounted it on a small pc board and coupled a short, single-turn pickup loop to the local oscillator in the tuner. Oscillator operation wasn't affected because very little energy is required to drive the CA3179. The CA3179E is readily available and inexpensive.* If you're adding the scaler to another type of tuner, use the minimum coupling necessary. Make it mechanically secure, and keep the lead lengths short.

Tuner checkout

Attach a 7805 three-terminal regulator to the UHF tuner so it's powered when the tuner is on. Check the operation of the scaler after the scaler installation is complete and the resistors are mounted on the tuner as shown. Connect the tuner to a temporary test source of +12 volts. Then connect the output of the scaler to a frequency counter, and monitor it while you adjust the varactor tuning voltage over the range of 0 to +32 volts. Look for any dropout in count. If any loss occurs, make a minor adjustment to the

* Jameco Electronics, (415)592-8097. Stocks all the ICs and most of the small parts used in this project. $20 minimum order.

FIGURE 3



Spectrum analyzer 10.7-MHz IF assembly continued from page 12.

PARTS LIST

FL1	15-kHz crystal filter, optional
FL2,FL3	Murata ceramic filters, 280 kHz
K1	DPDT miniature relay, contacts parallel, for pc mounting
K2	DPDT miniature relay, for pc mounting
K3	SPDT relay
L1	14T no. 22 tapped at 3 and 10 turns, 52 MHz
L2	9T no. 22 tap at 6T from bottom, 52 MHz
L3	Amidon L33-10 1T primary 10T secondary, 63 MHz
L4	12T no. 22, 10.7 MHz or 10.7 MHz IFT
Q1	40673 MOSFET
X1	52.3-MHz overtone crystal HC-18 case
IFT	10.7-MHz miniature IF transformers, interstage

VCO/scaler coupling and recheck until the scaler operation is reliable over the entire varactor voltage range. The VCO frequency is the counter reading multiplied by 256; the signal frequency is the VCO frequency minus the first IF frequency, 63. You now know the exact tuning range of your tuner. I obtained counter readings of from 1.838 to 3.793 MHz, equal to a VCO frequency of 470.5 to 971 MHz. The high end signal frequency was 971 − 63, or 908 MHz; the low end limit was 470.5 − 63, or 407.5 for 63-MHz IF frequency.

The IF circuit

Figure 3 shows the schematic of the dual conversion IF strip. This is a crystal-controlled, double conversion receiver, which uses either a Motorola MC3356 or an RCA CA3089 FM detector. The AM output of the detector is the analyzer output to the oscilloscope; the FM output gives a speaker monitoring capability. I have built IF strips using both detectors and they work equally well. I would recommend the CA3089 because it's easier to find and doesn't require the TL082 op amp. I installed the narrow 15-kHz filter because I happened to have one in stock. It isn't used often.

The sweep circuit

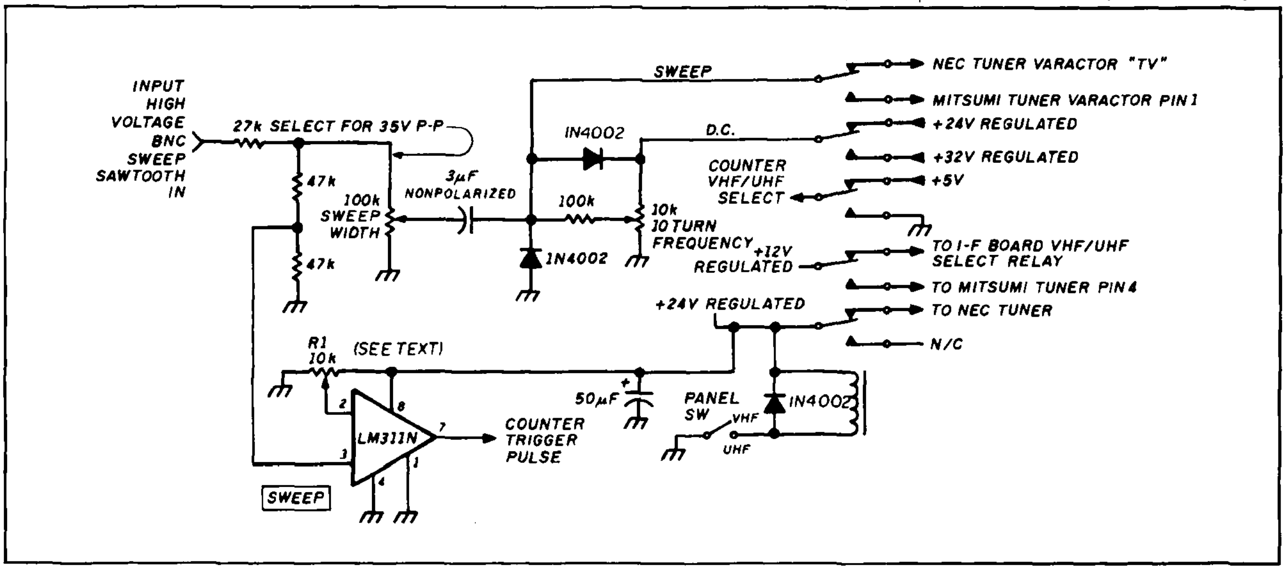
Most of the sweep circuit already exists in any oscilloscope. The circuit is WA2PZO's idea.* Find a point in the oscilloscope wiring where the horizontal deflection waveform has zero DC component. This would be the output of the complementary transistor pair that drives the H deflection plates. Usually there's an unused Z axis jack that you can use to bring this signal out of the scope. Proceed with care when making this modification. High voltages are present in any oscilloscope. Measure the p–p voltage at this point; it will probably be well over 100 volts.

Figure 4 shows the analyzer's sweep circuit. There should be about 35 volts p–p across the sweep width potentiometer. Change the value of R2 to obtain the correct voltage. A multicontact relay lets you switch the various voltages and change tuners with a single panel switch. The diode clamps in the sweep potentiometer circuit prevent the sweep voltage from exceeding the supply voltage on either band.

The sawtooth ramp from the oscilloscope is really a

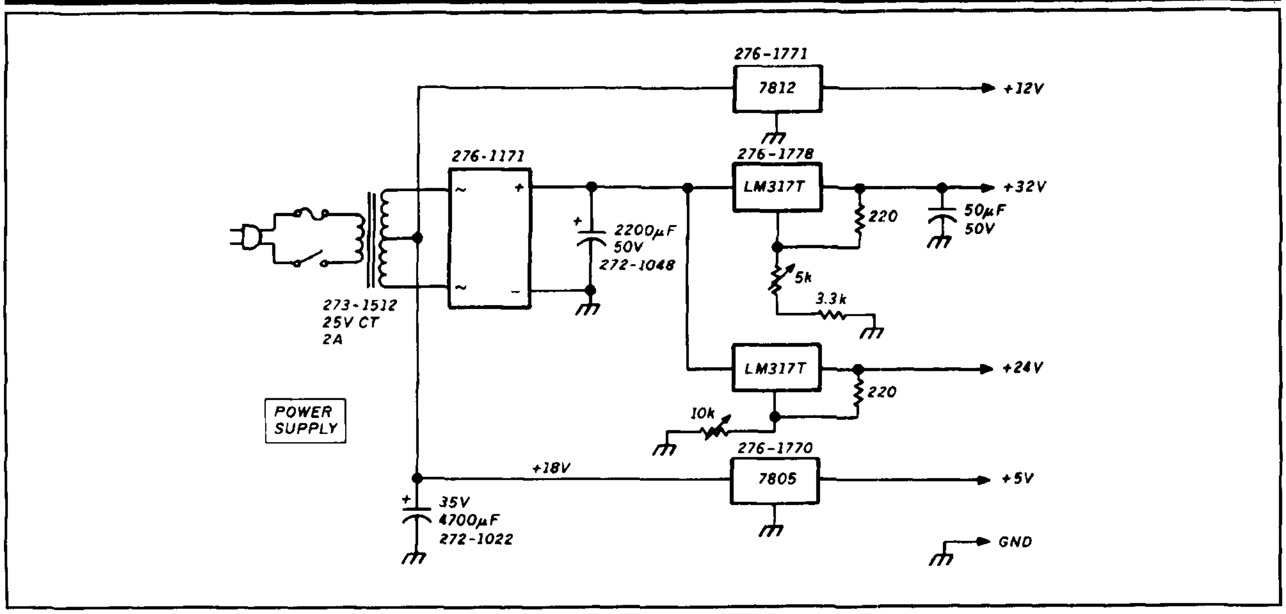
* Science Workshop, Box 310, Bethpage, New York 11714. Carries the NEC cable tuner and some other parts

FIGURE 4



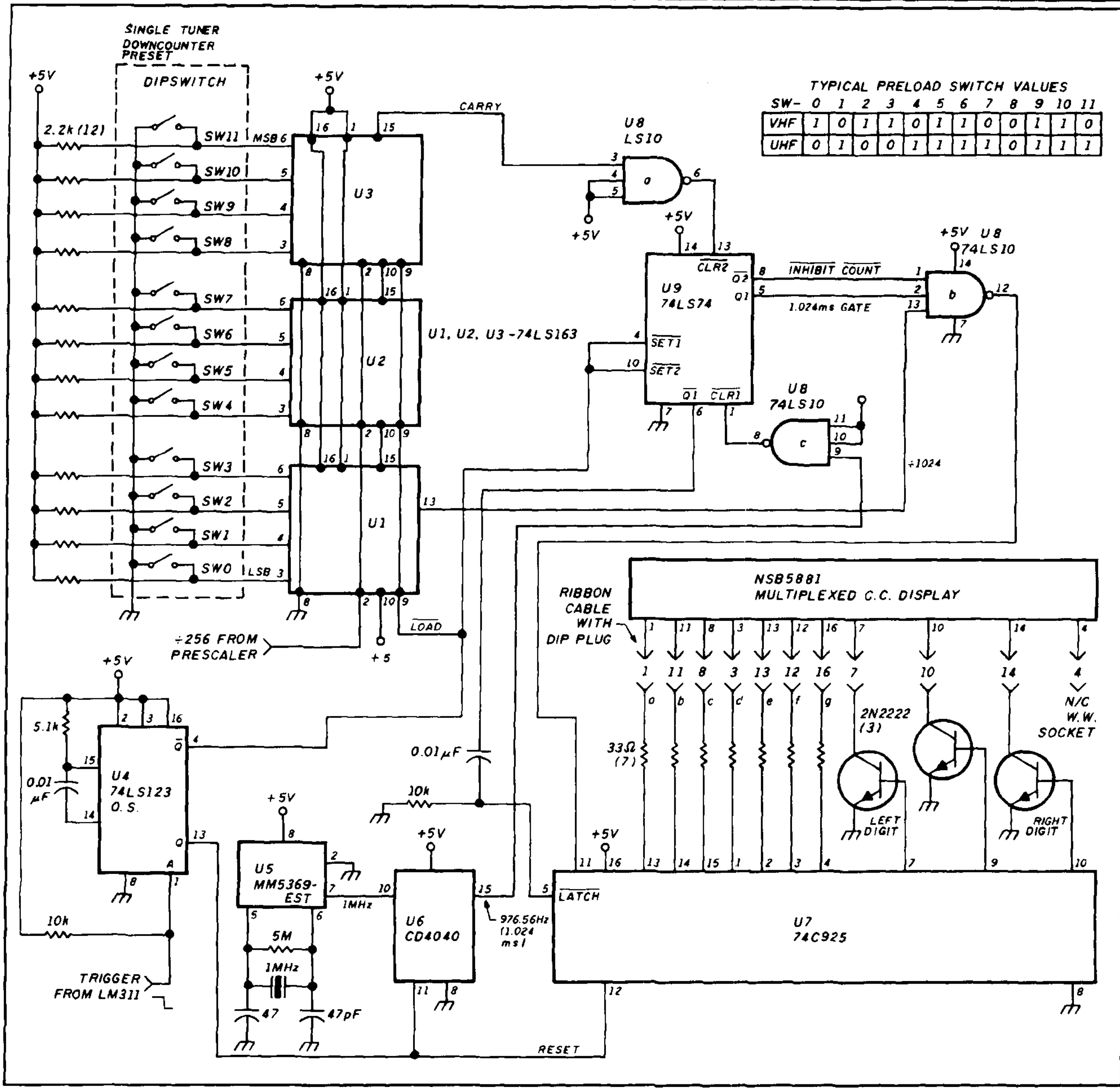
Sweep circuit of the analyzer.

FIGURE 5



Multiple voltage power supply for the analyzer.

FIGURE 6



Basic counter drawing.

rapidly changing DC voltage. The LM311 switches its state at an adjustable point (set by R1) on this ramp, which sets the exact time during the sweep that the frequency display samples the scaler outputs.

The power supply

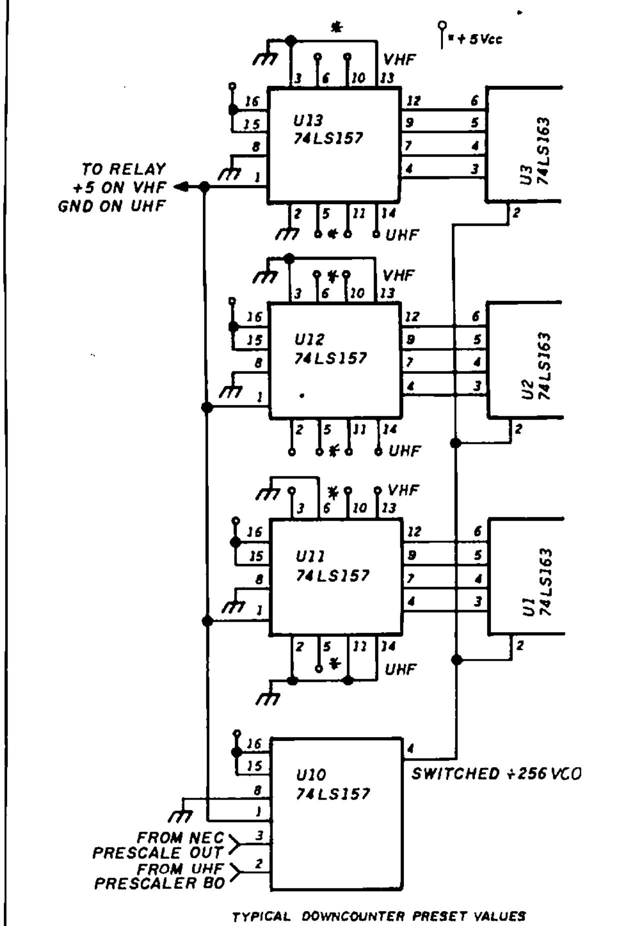
The analyzer required four voltages: +5, +12, +24, and +32. The easiest way to get these voltages is to use the circuit in **Figure 5.** I mounted all the power supply components, with the exception of the transformer, on a 2-3/4 x 5" single-sided pc board. Radio Shack stocks most of the parts.

The counter circuit

The timebase of 1.024 milliseconds in the counter is a little unusual. It's in binary instead of the usual BCD because the scalers divide by 256 instead of powers of 10. Consequently, all the rest of the timing values in the counter are binary.

Figure 6 shows the counter circuit. This is the basic circuit, with typical preload switch values for a 12-bit dip switch. I used this circuit while working on the 0 to 400-MHz tuner frequency display. The switches made it easy to adjust the counter to compensate for the unknown frequency offset

FIGURE 7



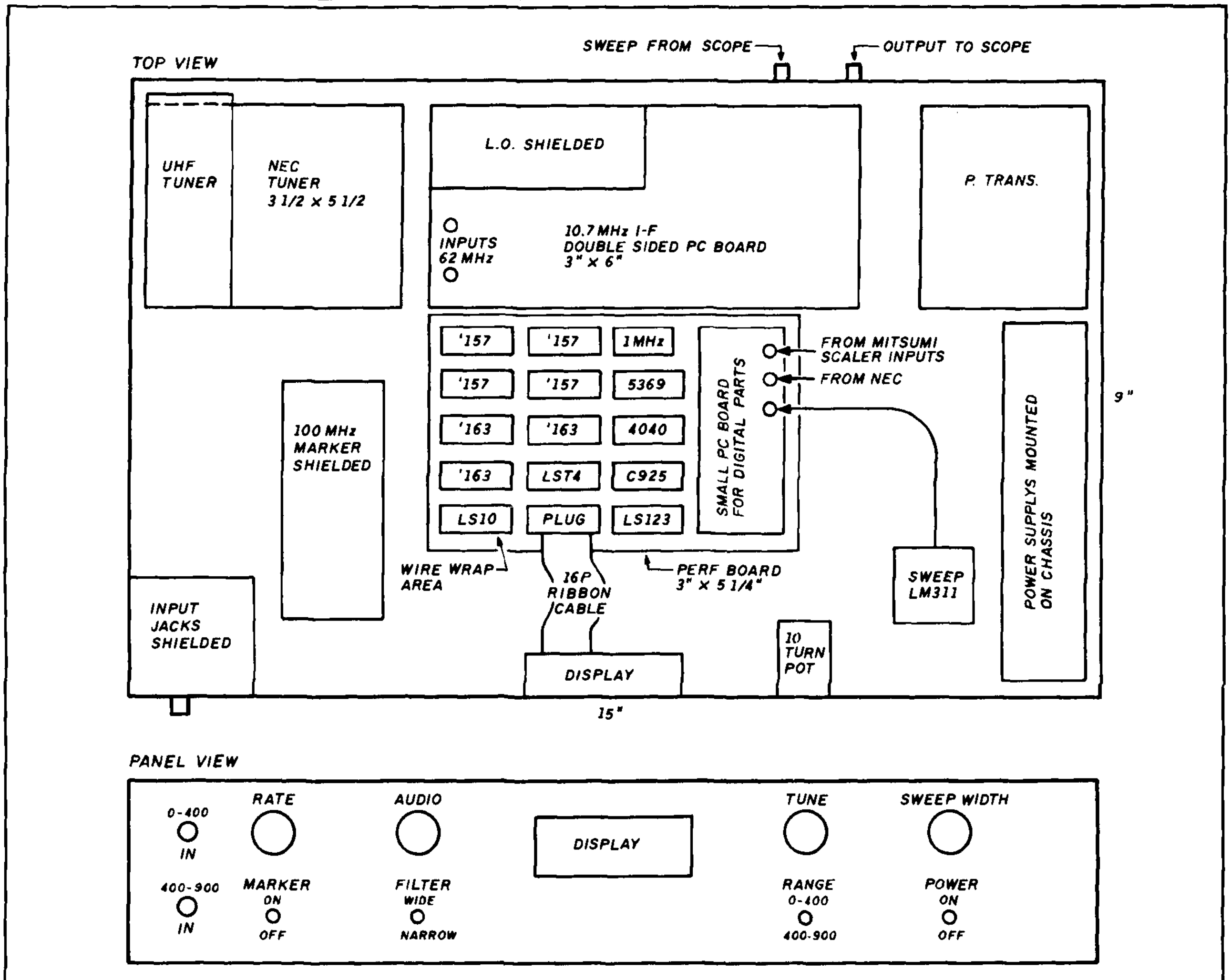
Adding automatic preset switching for VHF and UHF to basic counter drawing.

of the local oscillator in the NEC. (I later found it to be 610 MHz.) I determined the correct switch settings for the UHF tuner, and then had to find a way to enter these binary values into the system when switching between tuners.

Data selectors U11, U12, and U13 do this by acting as a 12-pole two-position switch. The circuit in Figure 7 shows the data selectors hard wired so the correct binary switch presets are present at the IC inputs. One section of U10 selects the correct scaler. This is a flexible arrangement which can be used with another brand of cable converter and/or another UHF tuner. Just find the preload values with dip switches, then replace the switches with data selectors.

The counter circuit works as follows. A value equivalent to the oscillator's offset in the tuner is preloaded into U1, U2, and U3 when one-shot U4 is toggled as the LM311 detects center line crossover of the sweep. U4 resets U6 and U7, and sets both sections of U9 — a dual RS flip-flop. At this point, U8 pin 2 is enabled and the count signal is at pin 13, but the gate doesn't pass the signal because pin 1 is low and the NAND gate is inhibited. U6 starts counting clock pulses to establish a 1.024-ms timing interval. U1, U2, and U3 count down from the preset value until they

FIGURE 8



Chassis layout. (A) Top view. (B) Panel view.

reach zero, and output a borrow pulse at U3-15. The borrow is inverted and clears one section of U9, enabling U8-1.

U8 starts to pass prescaler pulses, which are divided by 4 in U1. This continues until the 1.024-ms time interval has elapsed. At this point, U6-15 goes high, inverted in U8-8. The section of U9 that has been keeping U8-2 enabled suddenly goes low, and stops the counting in U7. When U9-1 is cleared, U9-6 generates a pulse transferring the new count to U7's latch and display circuitry. U7 displays this value until the next count is completed and transferred into the latches. U7 supplies current to the multiplexed seven-segment display in a standard circuit using transistors to switch digits.

Mechanical construction

The unit is housed in an inverted 15" × 9" × 3" aluminum chassis. The circuit boards are mounted on standoffs similar to those in the TVRO in the Gibson articles.[5,6]

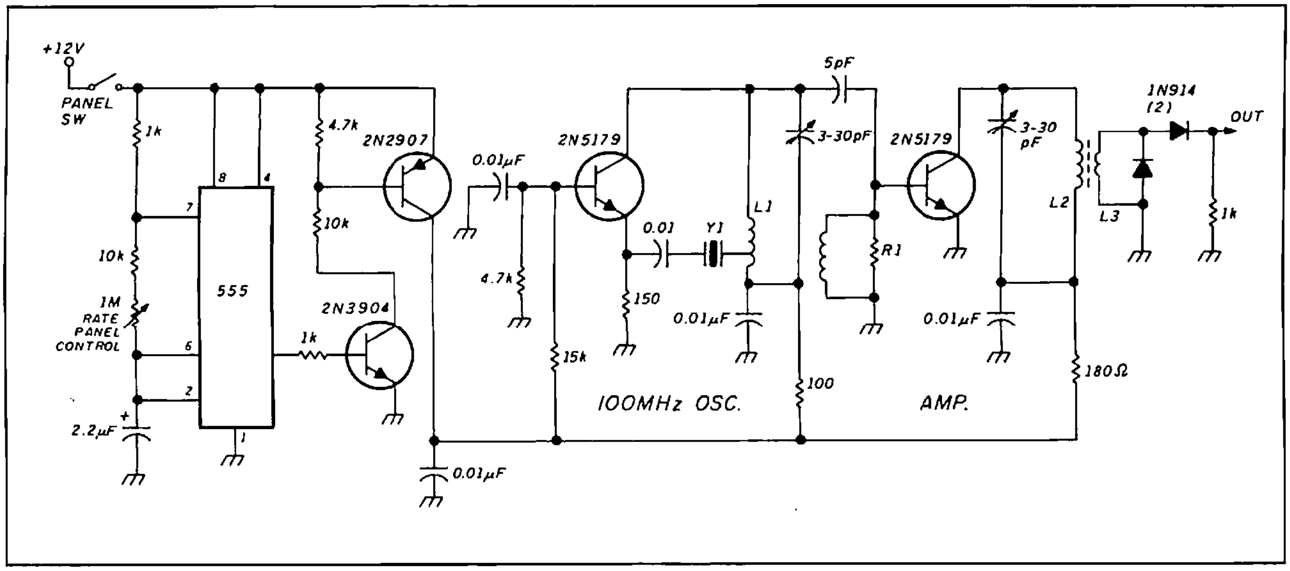
The counter circuit was wire wrapped and the layout is shown in **Figure 8**. It's advisable to shield the counter assembly completely because of the digital noise. I built the IF/detector circuit on a double-sided pc board because it provided an excellent way to eliminate feedback and reduce shielding problems. I now use wide masking tape as resist, and trim it with an X-acto® knife to make the pc trails.[7] *It's inexpensive and easy to work with.*

There are two BNC jacks on the panel for the two signal inputs. I shielded these jacks with scrap pc board material. I used two more BNC jacks at the back of the chassis for sweep in and signal out.

The marker generator

You'll need a marker generator (shown in **Figure 9**) to verify that the counter is working correctly and to help in initial setup. Even though everything now works properly, I still use the marker generator when I start out to verify that

FIGURE 9



100-MHz marker.

PARTS LIST

L1	***Air wound 7T no. 16 tapped at 1T 1/4" diameter, 1/2" length***
L2	***T50 torold 7T no. 22***
L3	***4T no. 22 over L2***
R1	***47 ohm 1/2-watt with no. 30 wire wound full***
Y1	***100-MHz crystal (Texas Crystals)***

All other resistors 1/4 watt
0.01 μF-capacitors are miniature disc

all is well. I used a circuit which pulses the marker on and off to make it stand out.

The marker generates harmonics of 100 MHz up through 900 MHz. You may have to experiment a little to get the oscillator circuit that works best with your crystal. The one shown is the best of the several I tried. Build the marker last, and use your working analyzer. You'll wonder how you got along without it. hr

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4. *The ARRL Handbook*, ARRL, 1987, pages 25-43
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A TRANSMIT CONTROL FOR MOBILE OPERATION

By James M. Bryant, G4CLF, 16, Church Road, St. Marks, Cheltenham, GL51 7AN, U.K.

Recent editions of the *Highway Code* for Great Britain recommend that drivers do not use hand-held microphones while at the wheel of a car. Many Amateur operators are now using boom microphones attached to a headband, the seatback, or the sunvisor. These microphones leave both hands free for driving.

The driver/radio operator still has the problem of switching his transceiver between receive and transmit. A common solution is VOX or voice operated transmission — a circuit which switches from receive to transmit whenever the operator speaks. While useful, this has several disadvantages in a motor vehicle:

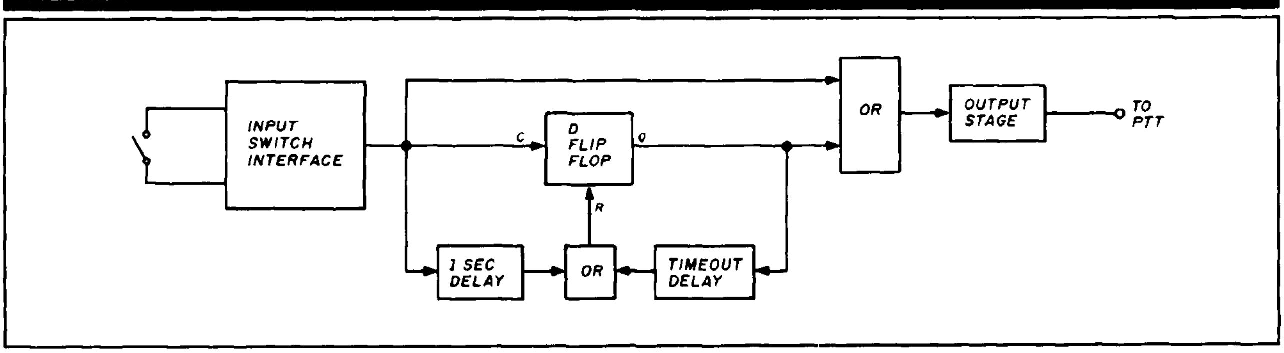
- While a well-designed VOX circuit will reject noise from the receiver of the rig it is being used with, it will still respond to the loud external noises common in a motor vehicle.
- A VOX causes the transmitter to transmit anything the operator says — even if it is addressed to another person in the vehicle (or another driver!). This function makes VOX operation rather inconvenient.
- It may also respond to speech from a broadcast receiver; many operators listen to the car radio while monitoring Amateur frequencies.
- VOX circuitry needs careful adjustment if it is to respond properly, particularly over a wide range of ambient temperatures.

The circuit to be described is a substitute for VOX. It requires the driver to operate a push-button switch to start and finish a transmission; this only requires the use of his hand for about as long as any of the other vehicle controls. (A foot switch, like an old-fashioned headlamp dip switch, might also be used.) The circuit also has other useful features.

Operating features

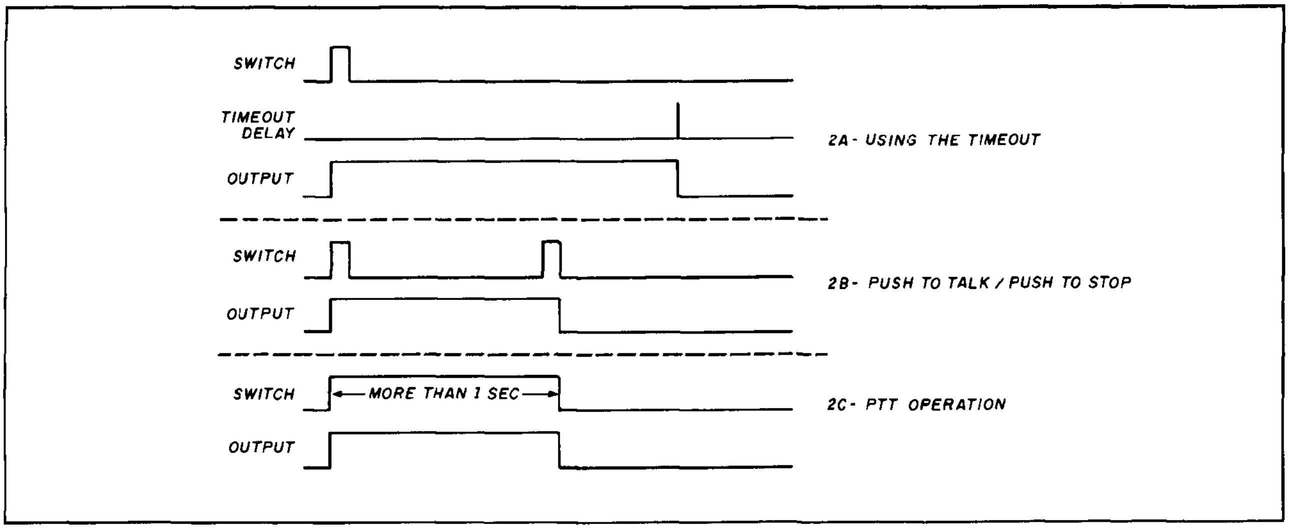
The control consists of a single push-button switch. If it is pushed briefly the transceiver starts to transmit and continues to do so until either the button is pushed for a second time and released, or a preset time interval is exceeded. (This causes the transmitter to time out before a repeater does.) If the button is pushed and held down for more than a second, the transceiver will transmit only until the button is released. This combination is very useful. To make a short call (but longer tnan a second) the button is used like a conventional push-to-talk (PTT) switch, for longer transmissions it need only be touched once at the start and again at the

FIGURE 1



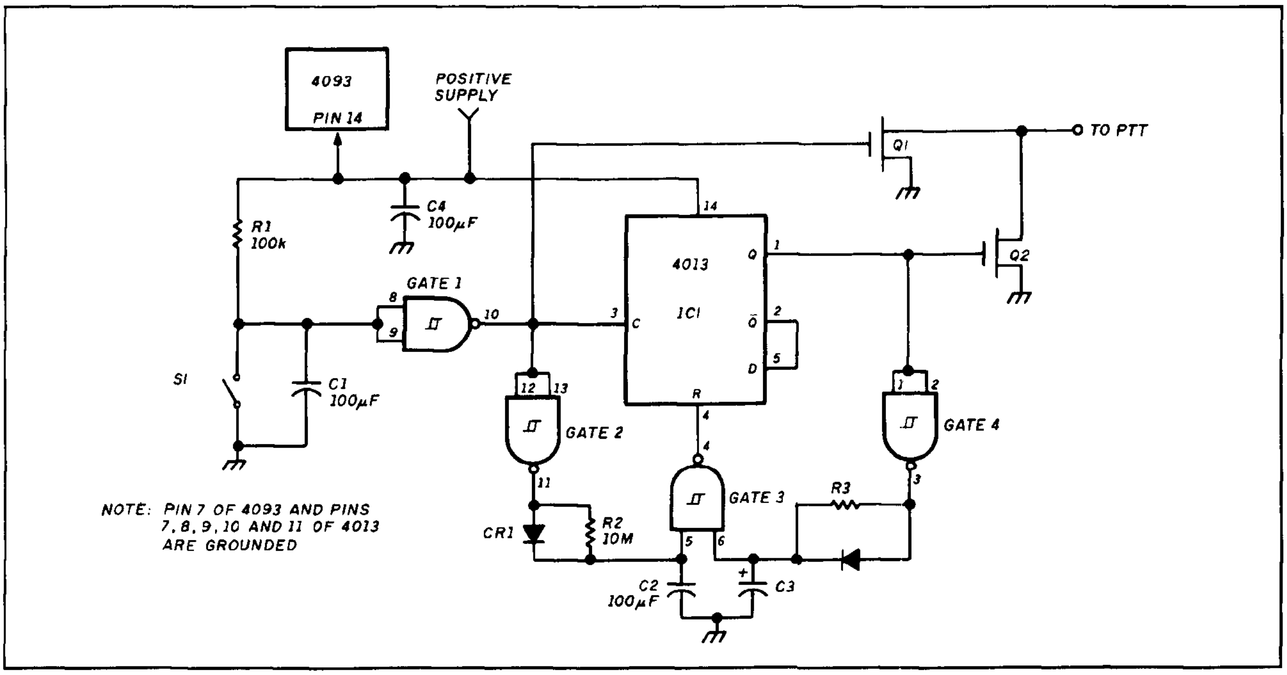
System diagram of control circuit.

FIGURE 2



Waveforms of different modes of operation. (A) Using the timeout. (B) Push to talk/Push to stop. (C) PTT operation.

FIGURE 3



Circuit diagram.

end. If the transmission exceeds a preset time it is ended automatically. The last feature has three benefits:

- It prevents garrulous individuals (like the author) from talking interminably.
- When operating through a repeater with a time-out it prevents one from wasting breath talking and not being relayed.
- If the button is touched accidently it limits the length of the unintended transmission. This last feature is quite useful as it is by no means uncommon to have repeaters blocked out for a considerable time by a mobile station who has accidently gone to transmit with a PTT locking device.

System description

A functional diagram of the control is shown in **Figure 1**. It consists of a flip-flop, two time delays (one of **1** second and one of whatever timeout delay is required), two gates, and a switch to operate the PTT line of the transceiver being used.

The various modes of operation are shown by the waveforms in **Figure 2**. In every case the flip-flop changes state when push-button switch S1 is first operated and both time

delays start. The output of the switch and the Q output of the flip-flop go to an OR gate which drives the output switch.

If the switch is released at once, the short time delay is reset and the Q output of the flip-flop holds the output switch closed *until* the *long time delay* is complete. The flip-flop is then reset (**Figure 2A**).

If the switch is pressed again during the delay (**Figure 2B**) the flip-flop changes state again and the long time delay is reset, but the output switch is held closed by the signal directly from the switch until S1 is released.

If, when S1 is first pressed, it is held down for longer than the first time delay (**Figure 2C**) the flip-flop is reset when the first time delay is complete, but the output switch is held closed (as in **Figure 2B**) until S1 is released.

Circuit Description

The system is built around two CMOS devices, IC1 (a 4013 dual D-type flip-flop) and IC2 (a 4093 quad dual-input NAND Schmitt trigger), two VMOS transistors, two diodes, three resistors and four capacitors. The circuit diagram of the controller is shown in **Figure 3**.

The circuit works because of the use of the 4093. A normal CMOS gate circuit has a linear region where small changes in input produce small changes in output; in other words it acts as an amplifier. A Schmitt trigger, on the other hand, is a "snap-action" device. If the input is changed the output remains unmoving until a threshold is passed, when the output switches to its new value. However, if the input is then moved backwards it must move some distance back (called the "hysteresis") before the output snaps back to its original state. The characteristics of a normal CMOS gate and a Schmitt trigger gate are shown in **Figure 4A** and **Figure 4B**, respectively.

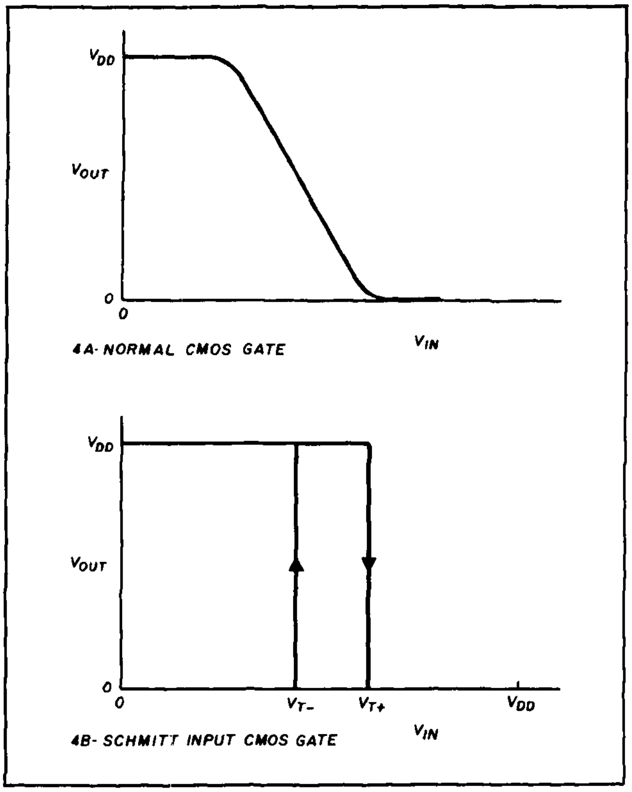
CMOS Schmitt triggers have very high input impedance so there will be a delay between the input changing state and the output if they are driven via a resistor/capacitor timing circuit (**Figure 5A**). If there is a diode in parallel with the resistor, the delay when the diode is conducting will be minimal but the delay when the diode does not conduct will be defined by the resistor as in **Figure 5B**. You can thus use CMOS Schmitt triggers to make time delay circuits which reset very quickly. Of course, NAND CMOS Schmitt triggers can be used as simple NAND gates.

The operation of the circuit in **Figure 3** is quite simple. The input to gate 1 of the 4093 is held high by a 100-k resistor (R1) to the positive supply rail. The push-button S1 grounds the input to the gate, which causes its output to go high. Capacitor C1 (100 nF or 0.1μF) debounces the switch and also prevents RF from the transmitter from affecting it. If S1 is located a long way from the controller, a ferrite bead should be slipped over the wire near the gate to minimize RF pickup.

When the output of gate 1 goes high it drives the clock of flip-flop 1 (flip-flop 2 is not used and all its inputs should be grounded) and its outputs change state. This is because the $\bar{Q}$ output is fed back to the D input. The output of gate 1 turns on transistor Q1 and the Q output of the flip-flop turns on Q2. Either Q1 or Q2 will switch the PTT line of the transceiver.

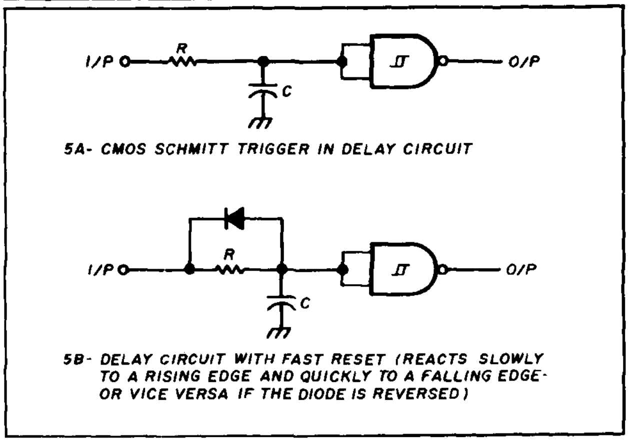
As well as driving the flip-flop, the output of gate 1 is inverted by gate 2 and applied, via a time delay of about 1 second formed by R2 and C2, to one input of gate 3 which drives the reset input of the flip-flop. As long as both inputs to gate 3 are high its output will be low, but if either goes low its output will go high and the flip-flop will be reset. The other input of gate 3 is driven, via a time delay formed by R3 and C3, from gate 4 which inverts the signal at Q. R3 and C3 could be driven directly from $\bar{Q}$ without an inverter, but since gate 4 is otherwise unused it is better to buffer the relatively large C3. The two diodes, D1 and D2, ensure that when the outputs of gate 2 and gate 4 go high capacitors C2 and C3 will recharge quickly.

FIGURE 4



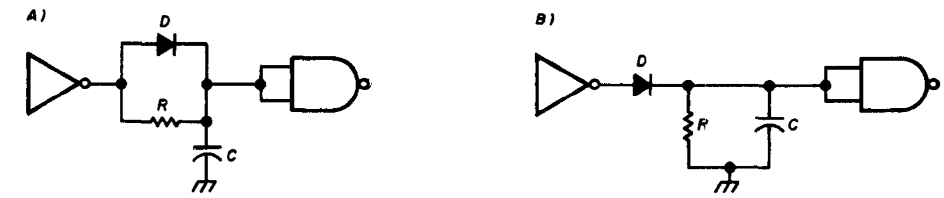
Comparison of transfer characteristics. (A) Normal CMOS gate. (B) Schmitt input CMOS gate.

FIGURE 5



Delay circuits. (A) Schmitt trigger in delay configuration. (B) Delay configuration with fast reset. (Reacts slowly to a rising edge and quickly to a falling edge — or vice versa if the diode is reversed.)

FIGURE 6



Respective current consumption of delay currents. (A) Low standby current. (B) Current flows in R during standby.

There are two subleties of design in the time delays. One is that the timing resistors R2 and R3 are driven by the gates as shown in Figure 6A. The circuit would also work if they were grounded as in Figure 6B, but the standby current would be several µA instead of a few nA. The other subtlety is that the timing capacitors C2 and C3 are fully charged in their standby state. This is unimportant so far as C2 (a ceramic capacitor) is concerned, but being biased continuously will reduce the leakage current of C3 — a tantalum bead electrolytic.

The circuit will operate from any supply voltage between +5 and +15 volts but its timing is affected by major supply voltage changes. It has negligible current consumption in its standby state and does not require an ON/OFF switch. An alkaline 6-F22 (PP3) battery makes an ideal power source, which should last for several years. During timing periods its consumption may rise to about 50 µA and while S1 is pressed it will draw nearly 200 mA.

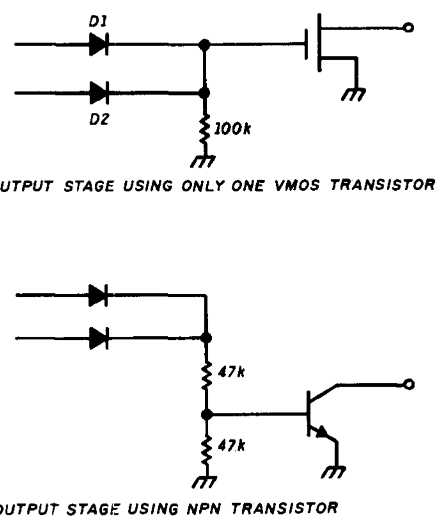
The output switch uses two VMOS transistors with their drains paralleled to give an OR function. They could be replaced by one VMOS device, two diodes and a resistor, as shown in Figure 7A, but this circuit increases the current consumption during switching by about 80 µA. If VMOS transistors are hard to obtain they may be replaced altogether by an NPN transistor (almost any small-signal type will do), two diodes, and two resistors (Figure 7B) but this will increase current consumption during switching to about 200 µA.

The output switch will only work with PTT lines that are grounded to operate. The VMOS device recommended, a VN10 from Siliconix, will work with positive voltages up to +50 volts and is capable of sinking 100 mA. If an NPN transistor is used the limit is about 80 percent of its Vceo rating. PTT line currents are generally less than a mA.

Timing

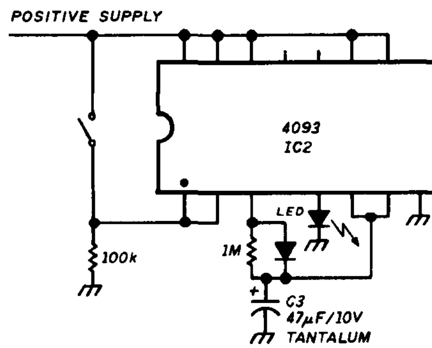
The threshold voltages of 4093 Schmitt triggers vary from device to device. It is not, therefore, possible to give values for R3 for particular delays. Some experimentation is necessary. Using the same 4093 and 47-µF tantalum bead capacitor that you are going to use in your finished equipment, build the circuit in Figure 8. Connect a p.s.u. or battery of the same voltage as the finished project and check that when the switch is closed the LED lights after a delay of a few minutes. Open the switch and leave the circuit powered for several hours for the leakage current in the capacitor to drop (leakage in electrolytic capacitors is always greatest just after they are powered up). Close the switch and time the delay until the LED lights.

FIGURE 7



Alternative output stages. (A) Output stage using only one VMOS transistor. (B) Output stage using one NPN transistor.

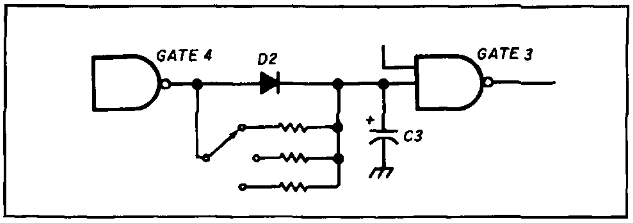
FIGURE 8



R3 timing test circuit. (Use same supply voltage as final circuit.)

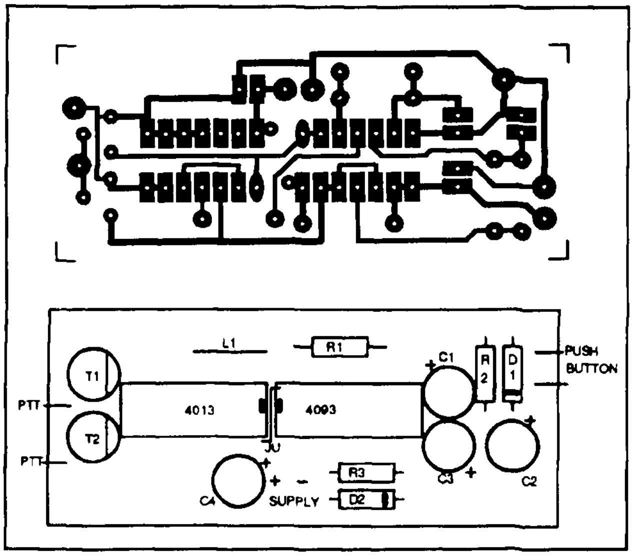
If this time delay is T seconds then the value of timing resistor that you must use for a delay of t seconds is t/T megs. When you have calculated this, replace the 1-meg resistor with the new value and check that it is correct. It is reasonable to find an error of up to 10 percent due to leakage in the capacitor and you may wish to adjust the calculated value to get a more accurate performance (increasing the resistor increases the time delay and vice versa). When you have finished these tests you can build the circuit using the components you have tested.

FIGURE 9



Variable delay option. If R3 is switched it must be switched at the end away from the input to gate 3.

FIGURE 10



PC board. (A) Foil side. (B) Component placement diagram.

COMPONENT LIST

Capacitors
C1,C2,C4 ***100 nF (0.1µF) 50 or 63 volt miniature ceramic***
C3 **47-µF 10-volt bead tantalum (observe polarity)**
(If the supply is more the +9 volts use a 16-volt capacitor.)

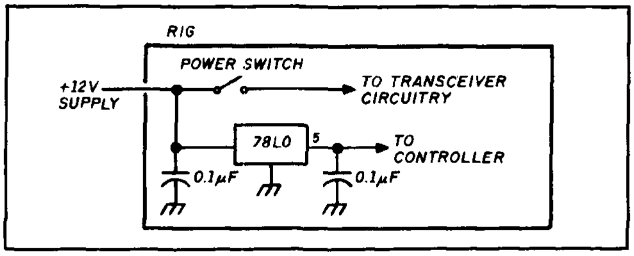
Diodes
D1,D2 ***1N914 or 1N4148 or any general purpose silicon diodes***

Integrated circuits
IC1 ***4013 (or CD4013, MC14013, etc.)***
IC2 ***4093 (or CD4093, MC14093, etc.)***
These are both 4000 series CMOS available from many manufacturers with slightly different letters.

Resistors
R1 ***100 k***
R2 ***10 meg***
R3 ***Several megs (see text)***
All resistors are 1/4 or 1/8 watt 10 percent

Transistors
Q1,Q2 ***VN10KM or VN10LM (Siliconix) VMOS transistors or any other small N-channel VMOS which can be switched with CMOS/TTL logic)***

FIGURE 11



Installing the controller in the rig.

If you want several different delays you can switch several different values of R3. It is important that the switch is placed at the end of the resistors connected to the output of gate 4 and **on no account** the end connected to the input of gate 3 (Figure 9).

Construction and connection

The circuit is very simple and may be built using almost any construction technique. A circuit board layout and placement diagram are shown in **Figure 10**; this is by no means necessary. The only important feature of the construction is that leakage currents at the positive terminal of C3 must be avoided.

The circuit and its battery are so small, and need attention so rarely, that they may be mounted almost anywhere. By adding a 75L05 regulator to prevent supply variations, you could mount them inside the rig itself. The power is taken from the unswitched side of the incoming +12 volts DC supply. The circuit timing in this case should be tested at + 5 volts and not with a 9-volt battery (see **Figure 11**).

Much more important than the mounting of the circuit is the mounting of the push-button switch S1. I have mounted mine on the transmission tunnel just behind the gear lever. The possibility of a foot-operated switch (to the left of the clutch) has already been mentioned, and many operators have switches on the gear lever itself. Other possibilities include steering column mounted switches (sometimes available from motor accessory shops) or a button on the steering wheel itself, although considerable problems arise from making connections which are not affected by rotation of the wheel.

Conclusion

I have been using this controller for over a year now and find it far more convenient than a VOX. It has proved very reliable in service and a major asset in preventing inadvertent repeater time-outs.

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A pc board is available for $1.75 plus shipping and handling from FAR CIRCUITS, 18N640 Field Court, Dundee, Illinois, 60118

A 2-METER CONVERTER WITH Q MULTIPLIER

Achieve high IMD rejection in dense signal environments

By Norman J. Foot, WA9HUV, 293 East Madison Avenue, Elmhurst, Illinois 60126

My original homebrew 2-meter converter, built in 1984, was designed primarily for reception of weak signals from the Oscar 7 and 10 (and later Oscar 13) Amateur satellites. I used a mast-mounted, low noise 20-dB gain preamplifier to minimize the overall noise figure.

While the loss of the coaxial cable leading into the station was only a few dB, I included an RF amplifier at the converter's input so that future installations could tolerate much higher cable loss without loss of overall sensitivity. Using this converter I made many exciting contacts around the world via Amateur satellites.

2-meter IMD

Lately I've become aware of what at first appeared to be 2-meter repeater signals in the Oscar 13 downlink frequency band. Further investigation showed these to be third-order IMD (intermodulation distortion) products generated inside my converter.

I don't remember encountering IMD interference from 2-meter repeaters until recently. There were probably fewer repeaters four or five years ago. Today, according to a recent repeater directory, there are over 40 repeaters in and around the greater Chicago area. Most of these are within 20 miles of my location.

Figure 1 shows typical 2-meter repeater activity in my region, as viewed on a spectrum analyzer. The repeater density in metropolitan areas like New York or Los Angeles is probably comparable to or greater than that shown in **Figure 1**.

My converter orginally used a 3N201 RF amplifier in the front end, with three high-Q tuned circuits. The gain was quite high and, consequently, IMD was a real problem — despite what would normally be considered reasonably good front end selectivity.

Third-order IMDs are spurious signals generated by nonlinear devices. An offending spur is located at a frequency equal to the difference between the second harmonic of one signal and the fundamental of the other. Some of these spurs may fall in the satellite passband. For example, if two repeaters are on at the same time, and one transmits on 146.61 MHz while the other transmits at 146.27 MHz, the third-order interfering signal would appear at 145.93 MHz — inside the Oscar 13 downlink passband.

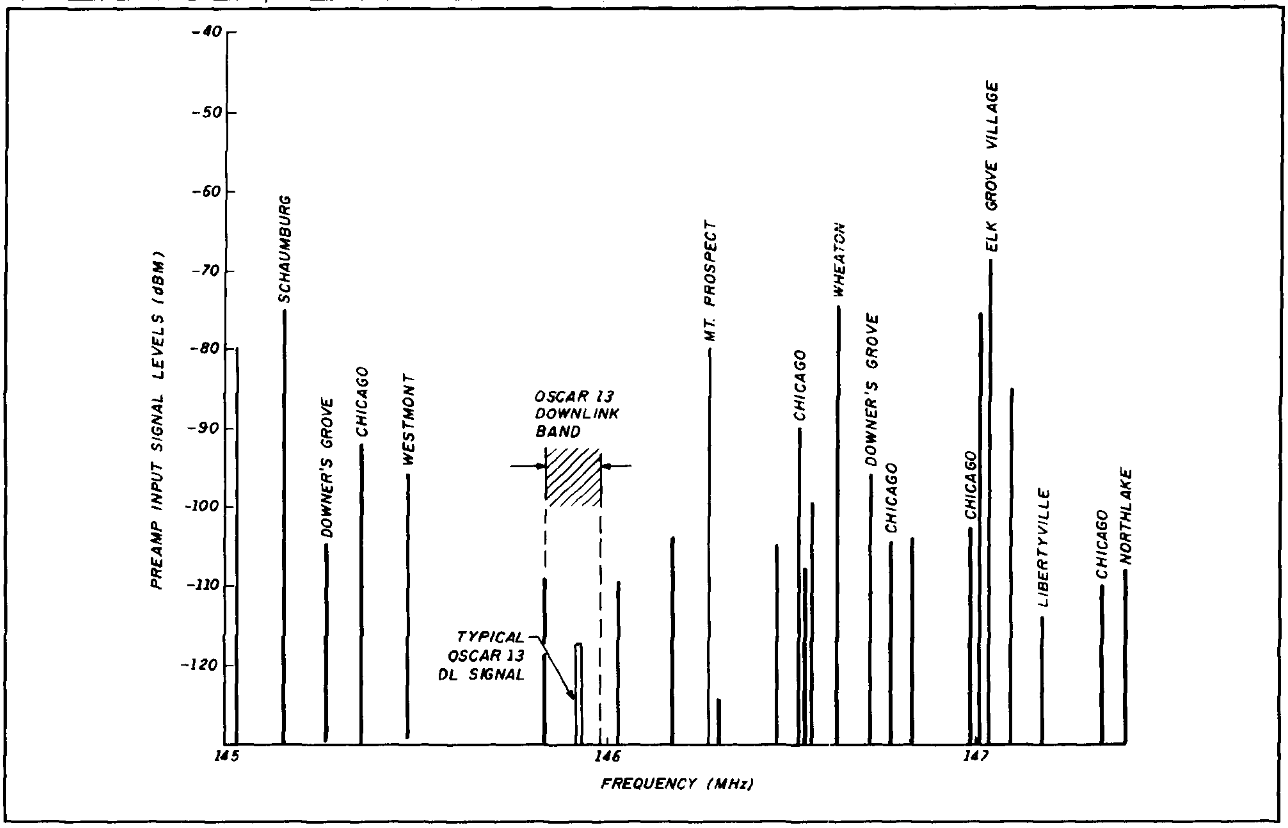
Preamp gain and linearity

A cursory inspection of the repeater frequencies in my area reveals that there are possibly a dozen frequency combinations that can produce IMDs that fall in the 145.825 to 145.975 MHz Oscar 13 downlink passband. These spurs are usually developed in the converter's first mixer. Generally, a preamplifier can handle high amplitude signals without producing significantly strong IMD, but its bandwidth and gain are large. Consequently, it amplifies unwanted (out-of-band) signals and passes them to the nonlinear mixer. My 2-meter preamplifier has 20-dB gain and is very linear, having a two-tone intercept point at about 12 dBm as shown in **Figure 2**. The possibility that it would cause IMD is remote; however, its bandwidth is very large. (See **References 1, 2** and **6** for information regarding the theory of intermodulation distortion.)

Signal analysis

Assume that you have two repeater signals delivered by the downlink antenna, each at −50 dBm levels. They are amplified to −30 dBm by the preamplifier, and possibly to −20 dBm by the converter's RF amplifier. The third-order IMD for this condition was measured on a spectrum analyzer to be 40 dB below either of these signals. This is equivalent to a −90 dBm signal at the antenna, much

FIGURE 1



Typical spectrum of activity. (Downlink antenna at 45 degree elevation.)

stronger than some Oscar 13 downlink signals.

Another factor influencing IMD is downlink antenna directivity. IMD is more noticeable if the satellite is near the horizon, when the downlink antenna may be pointing directly at a repeater.

Once a spurious signal has been generated, no amount of IF selectivity can reduce it. Corrective action boils down to providing the least amount of preamplifier and RF gain consistent with maintaining adequate overall noise figure and minimizing front end bandwidth. It's generally a good idea to retain high preamplifier gain, but minimize RF stage gain. Reducing RF bandwidth is by far the most effective means for reducing IMD signals.

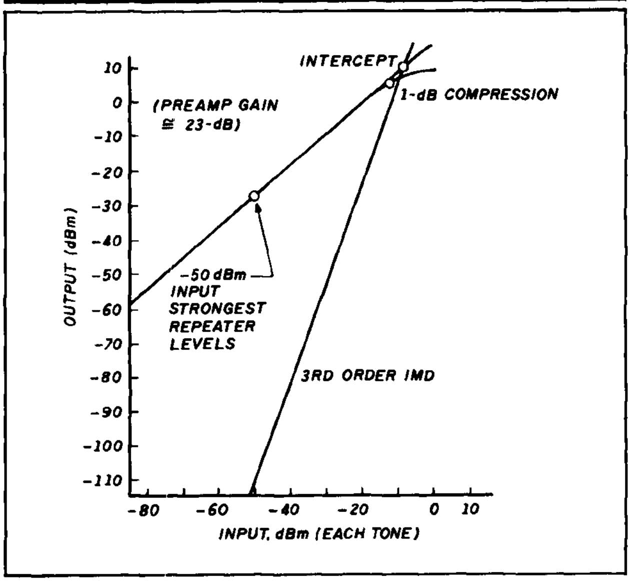
Q multiplier

Recently, I experimented (and had considerable success) with a 2-meter Q multiplier circuit in an attempt to produce an exceptionally narrow RF passband width. By definition, a Q multiplier is a selective amplifier with controlled regeneration. This may sound scary at 145 MHz, but read on.

After having shown by bench tests that repeater or other out-of-band signals could be responsible for IMD interference when given the proper conditions, I decided to build an outboard Q multiplier to perform actual tests using a 2N5486 JFET as the active element.

Preliminary tests showed that the RF bandwidth could be made extremely narrow — almost without limit — up to the point of oscillation. I located the breadboard ahead

FIGURE 2



Preamplifier IMD test.

PARTS LIST

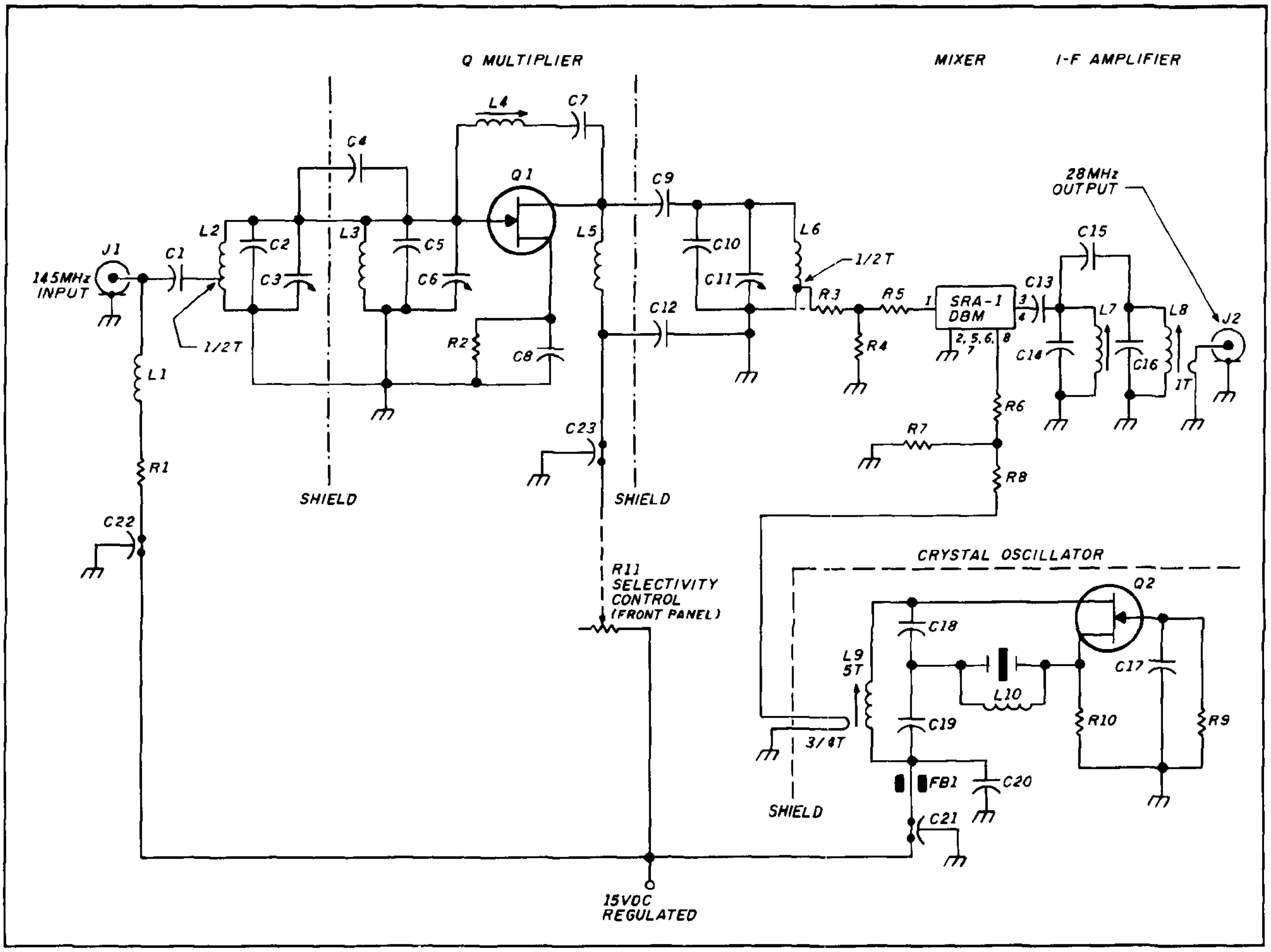
Capacitors	
C1	10-pF dip mica
C2,C5,C10	8-pF dip mica
C3,C6,C11	1 to 12-pF glass piston
C4	gimmick (see text)
C7	1000-pF disc
C8	0.01-μF disc
C9	39-pF dip mica
C12	0.1-μF disc
C13	5-pF dip mica
C14,C16	33-pF dip mica
C15	gimmick (see text)
C17	68-pF dip mica
C18	10-pF dip mica
C19	27-pF dip mica
C20	0.001-μF disc
C21,C22, C23	1500-pF feedthrough caps
Resistors	
R1	300 ohm 1 watt
R2	560 ohm 1/4 watt
R3,R5	22 ohm 1/8 watt, 5 percent
R4	51 ohm 1/8 watt, 5 percent
R6,R8	10 ohm 1/8 watt, 5 percent
R7	130 ohm 1/8 watt, 5 percent
R9	47 k 1/4 watt, 5 percent
R10	270 ohm 1/4 watt, 5 percent
R11	10-k pot (preferably ten-turn)
Miscellaneous	
Q1,Q2	2N5486
L1,L5	2.2-μH rfc
L2,L3,L6	six-turns no. 16 tinned busbar, 1/8-inch ID soldered to glass piston trimmers
L4	neutralizing coil (see text)
L7,L8	thirteen turns no. 28 enamel copper magnet wire on 1/4-inch OD ceramic Cambion coil forms, close spaced
L9	five turns no. 22 enameled copper magnet wire on 3/16-inch OD Cambion ceramic form
L10	0.33-μH rfc
X1	117-MHz 5th or 7th overtone crystal
FB1	ferrite bead, Fairite FB-101
J1,J2	BNC connector, UG1094 or equivalent
SRA-1	double-balanced mixer

of my converter, adding an RF attenuator pad at its output to limit overall gain. After I added a potentiometer to control bandwidth, it was obvious that the Q multiplier had indeed reduced the levels of the offending spurious signals. Except under unusual circumstances, the IMD was for all practical purposes eliminated. My next step was to modify the converter to include the Q multiplier in place of the original RF stage.

The converter

Figure 3 shows the overall 145-MHz converter including the Q multiplier, crystal oscillator, mixer, and IF amplifier. The Q multiplier is a variable gain, variable bandwidth RF amplifier. It drives a double-balanced mixer (DBM) through a 9-dB pad. A local oscillator (LO) signal is fed to the DBM through a 3-dB pad from crystal oscillator Q2. The 28-MHz IF output signal is the difference between the 145-MHz signal frequency and the LO frequency. A double-tuned 28-MHz filter feeds the IF output to J2. The converter will provide 144 MHz at an IF of 28 MHz using a 116-MHz crystal. If the converter is dedicated to Oscar 10 and 13 use only, a 117-MHz crystal is recommended; it will produce an IF of 28.825 to 28.975 MHz. Note that the decimal digits of 28 MHz then correspond to the 145-MHz decimal digits, enabling quick determination of the actual downlink fre-

FIGURE 3



Oscar 13 converter.

quency. That is, when the receiver is tuned to a downlink signal at 28.825 MHz, the actual downlink frequency is 145.825 MHz.

The neutralizing circuit consists of variable inductance L4, which tunes out the capacitive reactance of the gate-to-drain capacitance (including strays), as described in **References** 3and 4. This capacitance totals about 1 pF, depending on the circuit layout. At 145.9 MHz, an inductance of about 1.2 μH will resonate with this capacitance and stabilize the amplifier. Without this neutralization, the FET will probably oscillate, depending on the loaded Qs of the input and output tuned circuits and input-to-output shielding. To make L4, I wound 18 turns of no. 28 enamel copper wire spaced one wire diameter on a 0.2″ diameter fiber glass tube 0.75″ long.[5] The tube was fitted with a low permeability, powdered iron slug for adjustment. I painted the outside of the coil with a thin coat of 5-minute two-part epoxy cement. Although the epoxy sets quickly, it takes several days or more to cure thoroughly.

The mast-mounted low noise preamplifier that precedes the converter is powered by 15 volts DC, which is fed over the center conductor of the interconnecting coaxial cable for remote preamplifier operation. R1 is a 300-ohm 1-watt limiting resistor, used to avoid a catastrophic failure in the event the cable center conductor should short to ground.

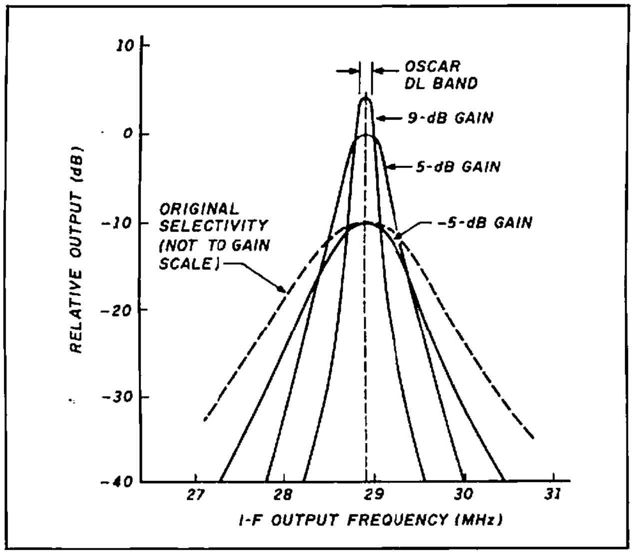
Capacitors C3, C6, and C11 are piston trimmers with the six-turn coils soldered to them directly with short leads. C4 is a fractional pF coupling capacitance made by soldering a short piece of no. 16 copper busbar to the high side of one coil and placing the other side against the high side of the other coil. A piece of Teflon™ sleeving prevents a short.

Gain and bandwidth

The Q multiplier bandwidth is controlled by potentiometer R11 located on the front panel of the receiver. Converter gain varies with the setting of this control and is highest when the bandwidth is narrowest. When the satellite is at apogee (maximum range), I adjust the control for minimum bandwidth (maximum gain). Signal levels are often very high when the satellite approaches perigee, so I increase the bandwidth. This, in turn, decreases signal levels at the mixer. Gain and bandwidth tend to compensate in terms of minimizing spurious signals.

Capacitor C15 is a special handmade capacitor which couples the two tuned circuits at the mixer output. It's made

FIGURE 4



Converter gain and bandwidth.

of two pieces of enamel-coated no. 22 copper wire fed inside a Teflon sleeve and overlapped about 3/8 inch. The far side of each wire is soldered to the high side of the respective coils.

Q multiplier adjustment

With the bandwidth control one turn less than fully clockwise, adjust the L4 tuning slug to a point just below oscillation. In the process, synchronously tune L2, L3, and L6 for maximum gain. Once set, the slug need not be readjusted. To check for proper setting, advance the bandwidth control fully clockwise and note that the amplifier oscillates.

Bandwidth

Figure 4 illustrates the RF bandwidth of the converter for various settings of the selectivity control, in terms of overall converter gain. The narrowest useful bandwidth is less than 200 kHz, corresponding to an overall converter gain of 9 dB. This setting provides maximum skirt steepness, which gives maximum protection from out-of-band signals. If the bandwidth control is advanced still further, the RF stage will oscillate. This is indicated by receiver quieting. Selecting the narrowest possible bandwidth requires knowledge of the control setting where oscillation starts. To facilitate smooth control, I use a ten-turn Bourns potentiometer. Note the dashed curve in Figure 4 which shows the bandwidth of the original converter for comparison.

Q multiplier benefits

It's clear from this set of curves that the Q multiplier is effective in terms of reducing and controlling front end bandwidth. Since I modified my converter to include the Q multiplier described here, I hear IMD developed in my converter from unwanted signals only on rare occasions and under unusual conditions. In addition, the bandwidth control is a handy means of setting gain to compensate for close-in and far-out satellite conditions.

My current interest is satellite communications, but the converter I've described may also be useful for 2-meter point-to-point communications, or whenever a dense RF environment may cause IMD interference. With the IMD problem now under control, I'm getting a lot more fun out of my satellite communications equipment. hr

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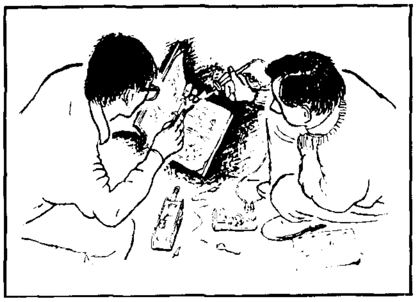
Ham Notebook



A Low Cost Battery Pack For Your Kenwood TH-25AT Handheld

I have a TH-25AT that I use for extended periods of time. Consequently, I need batteries with longevity. I looked into different batteries and discovered Kenwood's PB-7, an 1100 mAh. The capacity looked right, but the PB-7 was too large for my pocket. I continued my search and found the BT-6 empty battery case for $15.95. I added six 600-mAh NiCd batteries at $2.25 each.* My homebrew battery pack has the same capacity and is the same size as the PB-6 battery supplied with the HT and cost me just $29.95.

I used the BT-6 and PB-6 batteries for about a week and found they worked well. However, I had to remove the six batteries from the BT-6 battery case every evening and charge them in my NiCd charger overnight for the next day's use.

I needed an easy way to charge the batteries without removing them from the case, but the Kenwood-supplied BC-9 charger wouldn't slide onto the BT-6 case. I compared the BT-6 case and the PB-6 battery pack and found that the rail on the case next to the + terminal was longer. Using an X-Acto™ knife, I trimmed 0.28 inches to match the rail on the BP-6 battery pack. After I made this modification the BC-9 charger slid on, and I was set for a 15-hour charge without removing the batteries.

Those with a BC-11 charger who'd like to leave the batteries installed in the BT-6 case while charging can try a different modification. Just add two 0.25-inch square copper pads to the back of the case to mate with the contacts in the BC-11 rapid charger.

*The 600-mAh batteries can be ordered for $2.25 each from E.H. Yost and Company, 7344 Tetiva Road, Sauk City, Wisconsin 53583.

Modifying the BT-6

Remove the batteries and lay both packs back side up on your worktable. Cut two 0.25-inch square copper pads, smooth the edges with a file, and lay them on the back of the BT-6 case matching the location of the pads on the PB-6 battery. Mark their location and remove the pads. Drill two small holes in the center of the marked area using a bit no larger than no. 22 wire. Next use a no. 10 drill bit to countersink the holes on the outside of the case. Do this by hand only.

Take some no. 22 stranded wire, strip the ends of two wires a small amount, fan out the strands butting them against the center of the copper pads, and solder. Don't let the solder build up. The pads must fit flush to the back of the case. To check your work, pull the wire through the drilled holes to see if the solder area is too large. If it is, you may have to enlarge the countersink a small amount or reduce the solder area. When everything looks right, bond the pads to the case with a small amount of Krazy Glue™. Make sure the glue is dry before going on to the next step.

Route the wires inside the case to the terminals on the pads on top of the case. *Make sure* you are routing the wire from the *positive pad* to the *positive terminal* and the *negative wire* to the *negative terminal.*

Check with a continuity meter to see that the positive lead goes to the positive terminal and the negative lead goes to the negative terminal. After you've confirmed this, install the batteries as marked in the case. Now close the case, being careful not to pinch the wires. Using a voltmeter, make sure that the right pad is positive and the left pad is negative.

These modifications will let you charge your BT-6 battery pack in 15 hours with the BC-9 wall charger or 45 minutes using the BC-11 rapid charger. I've had this battery and charging system for the last seven months. I find it works very well and meets my needs for a second battery with a compatible charging system for the new Kenwood TH-25AT handheld.

T. H. Jenson, KE6WF

Control by Tones

The use of control tones in Amateur Radio is increasing. Although there are many different tone schemes, there are three systems in common use for Amateur Radio. They are: tone burst, Dual Tone Multi-Frequency, and Continuous Tone Controlled Squelch System (CTCSS).

Tone burst

Tone burst is usually a single burst of 1750 Hz at the beginning of a transmission. It is used extensively in Europe to access repeaters. Although fitted to some VHF equipment, it is not used in New Zealand.

DTMF

Also known in the United States as Touch Tone® , it is the system used with the push button telephones. These phones have oscillators to generate a pair of tones for each number on the key pad. The standards and available integrated circuits were developed originally for the telephone service. Now the technique is being used widely in Amateur Radio gear to enable operators to control intelligent repeater systems.

A bit of consideration is needed for fellow operators when using DTMF. It

is important to use your callsign and to comply with the radio regulations. It also helps other stations if you outline your intentions. In Wellington I use the following procedure to ask the Belmont 710 repeater for a report on my signal:

1. I dial up the 710 repeater in the normal way.
2. I say, "This is ZL2SX seeking a signal report."
3. I keep transmitting and, using the key pad, I dial 7 1 0 #. Then, without releasing the mic button, I say, "This is ZL2SX testing."
4. Finally, I let the button go and listen for the report.

As repeater systems become more intelligent, the use of DTMF signaling will enable us to "command" the system to do all sorts of fancy and useful tricks. DTMF commands will be used extensively on the National Link to be installed soon.

Dual Tone Multi-Frequency (DTMF) Standard

Frequencies: 697, 770, 852, 941, 1209, 1336, 1477, and 1633 Hz.

Tolerance: Nominal frequency ±1.5 percent.

Twist: All tones to be within ±3 dB of each other before transmitter preemphasis.

Deviation: The deviation of the 697-Hz tone will be 1.2 Hz.

Amplitude Range: The decoder will operate with tones +2 dB and −10 dB from nominal deviation.

The tones 697 to 941 are called the "low" tones and represent the rows of the keyboard from the top down. The "high" tones represent the keyboard columns from left (1209) to right. As an example, when you push the "8" key an 852-Hz tone and a 1336-Hz tone are sent together, ideally at the same level. Most Amateur Radio key pads have the 1633-Hz column tone needed for the full set of 16 digits (0-9,*,#, A,B,C,D). Most telephones have only 12 key pads, as A,B,C,D have no functions in telephone systems.

Note that the DTMF signals will pass through the link and most repeaters without serious distortion. However, in some applications, DTMF signals may be locally regenerated.

CTCSS

This is known by various trade names: Private Line, Channel Guard, SelecTone, and others. With this system, the receiver's squelch circuit disables the audio output until the specified subaudible tone is received. This means that your receiver will be quiet until it hears a call from a station using the system. There are 38 standard subaudible tones; encoders and decoders are available for most Amateur VHF and UHF sets. The Wellington VHF Group has been selling units for $35.

I use this system when I am expecting a call from my wife. Our rigs use the same CTCSS sub tone, and transmit it whenever the rigs are keyed. If we want to monitor for a call from each other but would rather not be distracted by other repeater users, we engage the CTCSS decoder and the radio is quiet until it hears the correct sub tone. It is a very effective system. There are restrictions on some of the tones, as not all repeaters are capable of retransmitting low frequencies.

Continuous Tone Controlled Squelch System Standard

Frequencies: Only EIA Standard tones recommended.

Tolerance: Encoder: nominal frequency ±0.1 percent.

Decoder: ±1 percent.

Deviation: 0.5 kHz.

Amplitude Range: The decoder will operate with tones +2 dB and −10 dB from the nominal deviation.

Response Time: For frequencies less than 100 Hz, 350 ms maximum. For frequencies above 100 Hz, 200 ms maximum.

Talk-off: Greater than 20 dB, 300 Hz to 3.4 kHz.

CTCSS may be required for some linking applications. However, the digital voice circuits used in link are designed to notch (more than 10-dB attenuation) tone frequencies up to 100 Hz. It is recommended that tones between 67.0 Hz and 85.4 Hz be used where CTCSS is used for control at a link end. Where users wish to use CTCSS for selective calling, tones between 123.0 and 250.3 Hz are recommended.

An understanding of the various tone control systems has given me more enjoyment in this great hobby of ours. I hope it does the same for you.

David Andrews, ZL2SX

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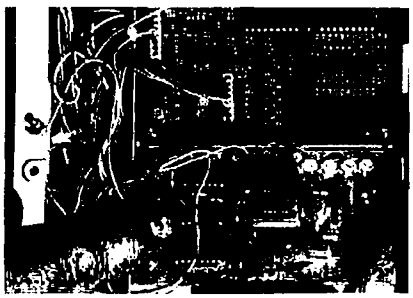
PRODUCT REVIEW

HF Add-on For ICOM IC-R7000 receiver

If you own an ICOM IC-R7000, or are thinking about getting one, consider this modification. A.R.E. Communications Ltd. of London, England, manufactures a board that can be installed in the ICOM IC-R7000 to add HF band receive capability. The board also adds 99 HF memory channels.

The HF kit contains a pc board with components, sixteen wires of various colors and lengths, three sections of coaxial cable, mounting screws, wire wraps, and detailed instructions. The instructions are clear and contain numerous well-labeled photos and diagrams.

The pc board mounts firmly to a spot which ICOM provided for placement of one of their accessories. Placing your A.R.E. board here ensures that it will be mechanically secure and electrically sound. It's important to follow the instructions step by step. Even though you install just sixteen wires between the board and the receiver, those connections are made all over the interior of a radio stuffed with components. I persuaded my friend Jay to modify his IC-R7000. Three and 1/2 hours later we had the modification in place and were ready to give the radio the "smoke" test.



Jay and I already knew the 7000 provided good reception on the VHF/UHF bands. After a quick check to be sure those bands were unaffected by the changes, we focused our test on the HF bands. The dimmer switch that used to control the brightness of the display now served as the toggle between VHF/UHF and HF receive capability. The instructions suggested that we use the first 30 memories on HF to store frequencies from 1 MHz to 30 MHz in one 1 MHz steps.

We made our unscientific HF evaluation by comparing the modified ICOM 7000 with a stock Collins KWM-380. Whenever we found an active frequency on the Collins, we could pick it up on the ICOM with similar signal strengths. Jay now has an all-mode receiver that can literally go from DC to 2 GHz for a cost of just $149 — truly a good investment.

The IC-R7000 HF kit is available from A.R.E. Communications, Ltd., 6 Royal Parade, Hanger Lane, Ealing, London W5A IET England. Telephone 01-997-4476 or FAX 01-997-2565.

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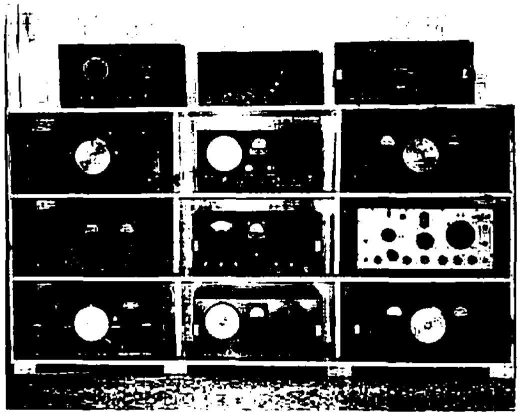
Circle #301 on Reader Service Card.

FAMOUS EQUIPMENT OF YESTERYEAR



The Hallicrafters' Sky Buddy, Sky Champion, and Sky Rider Defiant

By John Nagle, K4KJ, 12330 Lawyers Road, Herndon, Virginia 22071

Times have changed! Today when an Amateur wants to buy a new receiver, he begins by reading the specifications. Cost isn't a critical factor most of the time. But it wasn't always that way.

Note the prices as you browse through this issue of *Ham Radio*; numbers between $1000 and $2000 are common. Even the used equipment advertised in *HR*'s "Flea Market" has comparable prices. The present generation takes these numbers in stride; however, we members of the older generation are amazed. Many of us remember a time when we had trouble finding $29.50 to buy a Sky Buddy. What changes there have been in 50 years!

In the first days of store-bought equipment — during the Depression in the early 1930s — you usually started by reading the price list. A fellow knew how much money he had in his wallet, and that was his limit.

The Hallicrafters Company built its reputation offering affordable receivers for the Depression trade. The receivers may not have been the highest performance type available, but they did provide a lot of signal for the money. Many Amateurs, who might not have had a chance to get on the air, had the opportunity with a Hallicrafter.

I'd like to tell you about three Hallicrafters receivers that were popular among Amateurs of the day because of their low cost and correspondingly good performance.

The Sky Buddy

Amateurs remember different pieces of equipment for different reasons. Some remember the performance, while others remember unusual operating features. Some equipment may be especially treasured because it was used in a first QSO, or because the operator could afford to buy it and (as a result) get on the air.

The Sky Buddy, which went for $29.50, is remembered fondly because it was a good "buddy" to many aspiring Amateurs — especially to those teenagers who bought it during the Depression. Not many Amateurs had the resources to pay $185 for an HRO, or even $100 for an NC-100, but some could afford $29.50.

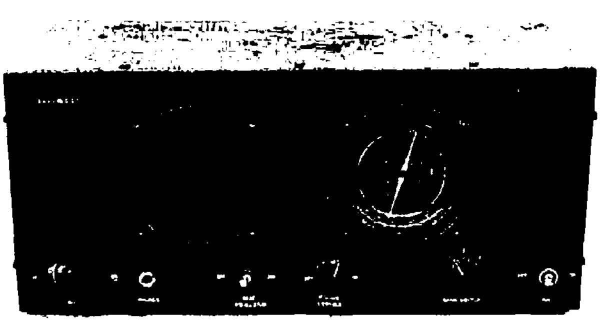
I remember my own Sky Buddy well. I was a junior high school student in the St. Louis area in the late thirties, and worked in the school cafeteria an entire semester to earn enough to buy one. I had been using a two-tube regenerative receiver described in the 1939 edition of *The ARRL Handbook* and was able to copy W9BSP's code practice transmissions from Olathe, Kansas, but 160 meters was the only band I could receive. Carrying the Sky Buddy home from the old Walter Ashe radio store on Pine Street was one of the thrills of my adolescence. I connected a 10-foot antenna strung around my bedroom floor, and the first station I heard was a W6 on 20 meters. I don't think any station since then has sounded as loud and clear!

I was also able to receive shortwave broadcast stations, especially those from Europe. Tuning across the SWBC bands in early September 1939, I heard Adolph Hitler announcing the march of the German Army into Poland. Even without the translation, I could tell by the tone of his voice that his speech was not conciliatory! But I wasn't mature enough to realize the effect that broadcast would have on everyone's lives.

The Sky Buddy also played another important role in my Amateur Radio life. I had always been sorry I traded in my Sky Buddy. In fact, I have yet to meet anyone who owned one and let it go who isn't sorry he disposed of it. Well, about 15 years ago I was walking through a hamfest flea market and saw one exactly like the one I had owned, in mint condition. I couldn't resist; I bought it! It was the first acquisition in what has become a collection of over 100 pieces of Amateur Radio equipment from the 1930s. I'm rapidly running out of space to keep my wife. (Wife's note: "You think he jests?")

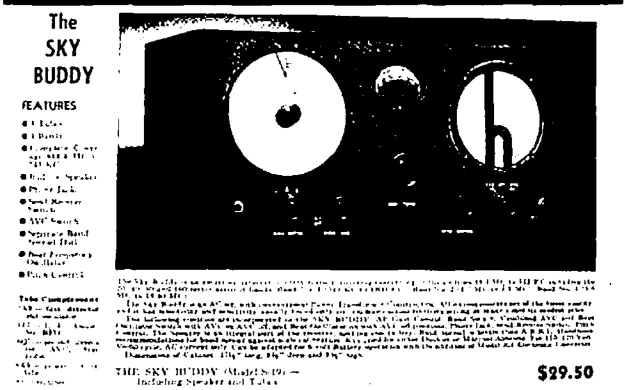
The original Sky Buddy, first advertised in the September

PHOTO A



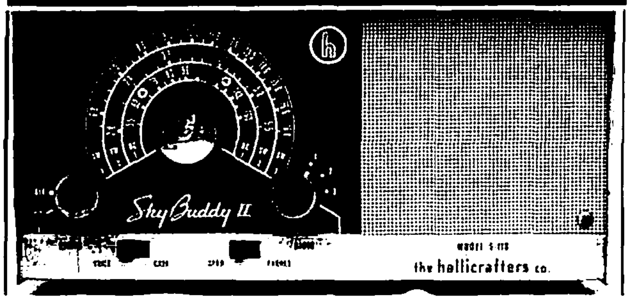
The original Sky Buddy.

PHOTO B



Hallicrafters' advertisement from the 1939 *ARRL Handbook* featuring the Sky Buddy S-19.

PHOTO C



The Sky Buddy II, the S-119.

1936 issue of *QST*, was also shown in the 1937 and 1938 editions of *The ARRL Handbook* (see Photo A). It was also known as a 5-T, for five tubes, all glass. Its frequency range was 550 to 18,400 kHz. A restyled version was announced in the May 1938 *QST*. It was known as the S-19, and also covered 550 to 18,400 kHz in three bands, but used four metal tubes plus a rectifier. This version is fairly rare. I've never actually seen one in good condition and would like to hear from someone who has one that I could photograph. Photo B shows a Hallicrafters' advertisement from the 1939 *ARRL Handbook* featuring the S-19.

In 1940, the Sky Buddy was redesigned again. A separate bandspread control was added and its frequency range was expanded to 40 MHz, which included the 10-meter band. This model, called the S-19R, is the one Amateurs generally think of as being "The" Sky Buddy.

There was actually a fourth version of the Sky Buddy — the Sky Buddy II — which came out after World War II. It was really just a glorified broadcast radio, not a real Amateur receiver. Photo C shows the Sky Buddy II circa 1948; it was called the S-119.

The name "Sky Buddy" has an unusual origin. According to Bill Halligan, the founder of Hallicrafters, when the receiver was in the prototype state Hallicrafters was trying to find a snappy name for it. A youngster nicknamed Buddy used to hang out around the Halligan backyard and help Bill with his yard chores. This youngster was so friendly and helpful that Bill named the new receiver after him. Unfortunately, Halligan was not able to remember Buddy's real name. I would be happy to hear from anyone who knows — especially from Buddy himself.

Looking back, I see that the Sky Buddy isn't one of those receivers remembered as having great capabilities — because it didn't. You may think of it affectionately as the affordable model that gave you your start in Amateur Radio, and a lot of pleasant listening.

The Sky Champion

If you were fortunate enough to be able to spend a little more to begin with, or if you'd just been given a raise and could buy a better receiver, the next step up was the Hallicrafters' Sky Champion.

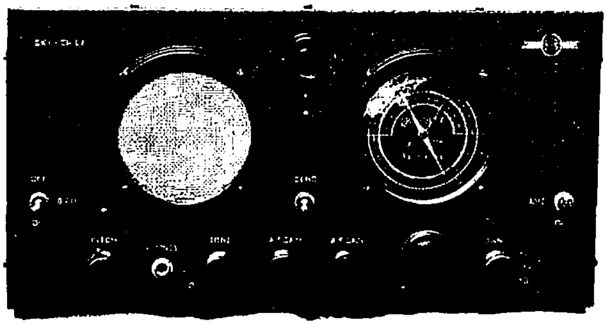
This family of receivers, while not the least expensive, could still be called low cost. The family included two receivers called "Sky Champion," and a third, which was actually the earliest, called "Sky Chief."

The Sky Chief was announced in the September 1936 issue of *QST*, along with the first Sky Buddy. The receiver featured an airplane-type, two-speed tuning dial, then popular for both broadcast and Amateur receivers. It had seven glass tubes (including an RF preselector, magic eye tube, and rectifier), a 5-inch speaker, band switching, and a tone control. Its price was $49.50, which was moderate for the time. The Sky Chief was less than any competing superheterodyne receiver except, perhaps, the National Company's FB-7 — which didn't have an RF preselector or direct reading tuning dial, and used plug-in coils. Photo D shows the Sky Chief. Its frequency range covered the broadcast band to 18.4 Mc/s (MHz today).

Hallicrafters' products were restyled early in 1938, and the Sky Chief was renamed the "Sky Champion." The tube count was increased to eight, five of which were metal. The magic eye tube was eliminated, and two more working tubes were added. The frequency range was extended to 44 Mc/s to add the 10-meter Amateur band and the 30 to 40 MHz emergency services sector, which was just beginning to be occupied. This version was known as the S-20 and is shown in Photo E.

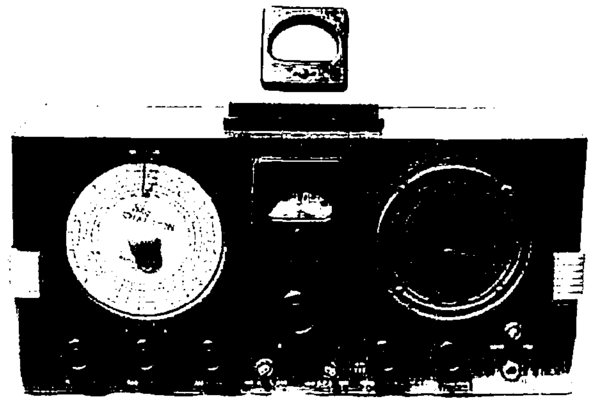
The S-20 provided an optional external S-meter to replace the magic eye tube as a signal indicator. This cost-saving measure was one of the ways Hallicrafters managed to hold the price down, yet still provide features that helped keep

PHOTO D



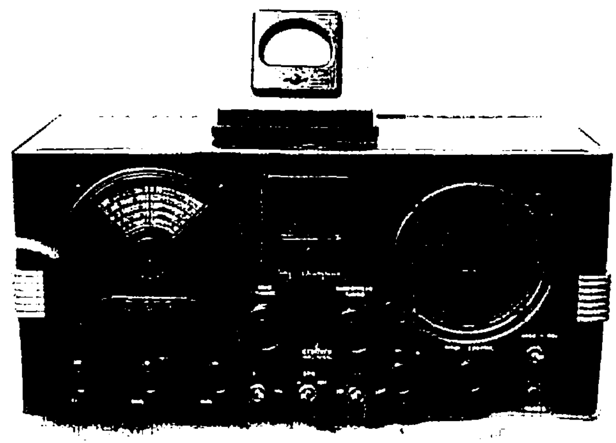
The Sky Chief.

PHOTO E



The Sky Champion S-20.

PHOTO F



The Sky Champion S-20R.

them ahead of the competition. For an additional $6.95 you could buy an external S-meter with a separate meter cabinet styled to match the receiver. The S-meter plugged into a five-prong socket on the rear apron of the receiver, as shown on top of the receiver in Photo E.

The RF gain control had a switch which closed in the maximum clockwise position (maximum RF gain) and illuminated the S-meter scale. Try putting an AC voltmeter across pins 1 and 5 of the S-meter socket on the rear apron and operate the switch; you should measure 6.3 volts AC.

These optional S-meters are hard to find. I've only seen one and its style is different from those shown in Hallicrafters' advertisements of the time. I'd like to hear from any collectors who have S-meters with different styling.

The December 1939 issue of *QST* announced a new version of the Sky Champion just in time for Christmas. The circuitry was upgraded to include electrical bandspread, a second tuning knob was added, and both tuning dials were illuminated. The newly developed Dickert automatic noise limiter was also included, increasing the tube count to nine. This version was known as the S-20R (see Photo F). The price remained $49.50, and Amateurs got even more for their money.

The S-20R was a very serviceable receiver. Like many of the receivers of the 1930s, its popularity depended more on its price/performance ratio than on performance alone. The Sky Champion series isn't a good performer on SSB because it uses a diode detector and because its bandwidth is designed for AM phone.

In spite of its simplicity, those who owned and used one remember it fondly. Novices and SWLs lucky enough to find one in good working condition will discover it makes an excellent starting point into radio.

The Skyrider Defiant

As the 1930s came to an end, the Depression eased and many who were hard-pressed in the middle thirties found their economic position improved. A better receiver was within their budget. Or, it may have been that many who were working in the radio business found their skills in greater demand as war came in Europe. Amateur Radio training and experience made Amateurs more sophisticated.

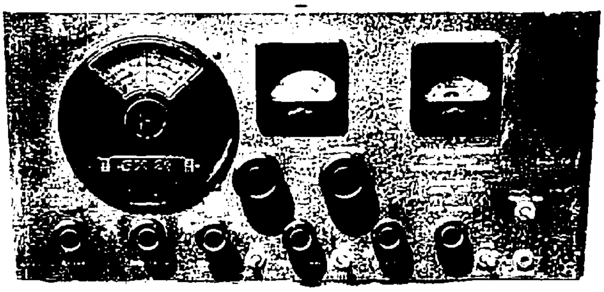
Receivers in the middle price range were becoming more important to both manufacturers and Amateurs. These receivers had to have enough refinements above economy class to make customers willing to pay more. But if they had too many goodies, they took sales away from the high profit, top-of-the-line equipment.

Receiver design had advanced from an art to a science by the end of the 1930s, and designers were able to offer a wider range of capabilities. Manufacturers were constantly judging ideas for midpriced receivers, evaluating which useful features they could add to a receiver without significantly increasing its cost. Equipment like S-meters and crystal filters became common.

Hallicrafters had established its name because of its policy of giving a lot of signal for a buck. They enhanced this reputation by developing two medium priced receivers: the Skyrider Defiant, the SX-24; and the Super Defiant, the SX-25. The SX-24 was first advertised in the July 1939 *QST*; it was the lower priced of the two at $69.50, plus $12 for a matching speaker. It had nine tubes, including one stage of RF preselection and single-ended audio output (see Photo G).

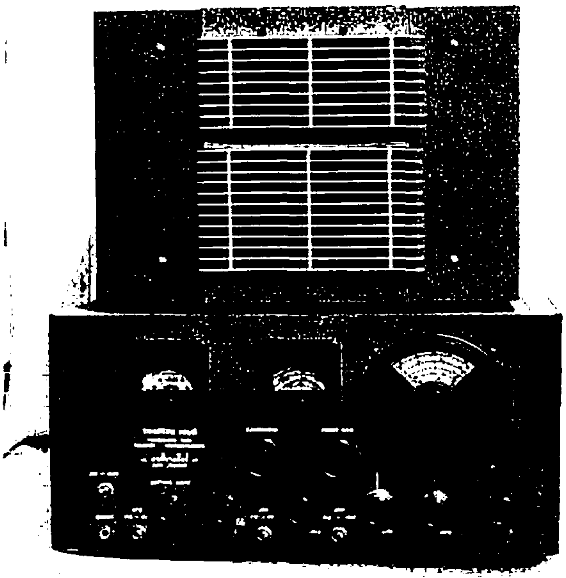
In February 1940 Hallicrafters announced the SX-25

PHOTO G



The Skyrider Defiant SX-24.

PHOTO H



The Super Defiant SX-25.

Super Defiant as a replacement for the very popular SX-17. The SX-25 cost $99.50, including a matching speaker. It had 12 tubes with two stages of RF preselection, an audio phase inverter, and push-pull audio output (see Photo H).

In the 1942 Hallicrafters' catalog these receivers were priced at $74.50 and $104.50, respectively. Besides an S-meter and crystal filter, which by the late thirties had become common in all but the lowest priced receivers, Hallicrafters added "frequency meter tuning." When the main tuning dial was set to one of four red lines (one for each of the Amateur bands, 80 through 10 meters), the bandspread dial was calibrated accurately in frequency for that band. This was a new concept which Hallficrafters soon adopted in their other receivers.

The two receivers appear quite similar except for their name, Skyrider Defiant or Super Defiant, and their model number, SX-24 or SX-25, embossed on the metal main tuning dial cover. However, there are less obvious differences in the bandswitch and selectivity switches located just below the main tuning dial. On the SX-24, the selectivity positions and the band numbers are silk-screened on the cabinet as are the rest of the control labels. On the SX-25, the labels for these two controls are embossed on the skirted knobs themselves.

Internally, the most striking difference is the additional tuning condenser (capacitor today) gang required for the extra stage of RF preselection. The SX-25 uses two 2-gang capacitors rather than one 4-gang capacitor, possibly because 2-gang capacitors were originally used on another receiver (like a Sky Buddy). It may be that two 2-gang capacitors were simply cheaper than one 4-gang capacitor. Another obvious difference is the increased tube count of the SS-25.

The SX-24 became a casualty of World War II; Hallicrafters didn't produce any of them after the war. The SX-25 was advertised in *The ARRL Handbook* in 1946, but not in 1947. Apparently, Hallicrafters needed a medium-priced receiver they could put into production quickly after the war, and chose the SX-25.

In retrospect, the Defiant family were medium priced receivers whose performance approached that of the high priced sets. They were widely used by Amateurs who could afford more than economy class, but not the luxury line. I believe they deserve more historical interest than they have received to date.

Summary

These low cost receivers have an important place in radio history because they were in a price range which put them within the budget of the majority of the Amateur community. This may be why they remain so popular among collectors and restorers.

Attention! All amateur photographers and artists...

Over the years many of you have read and responded to our calls for manuscripts. Now I have a new request for those of you whose talents lie in different directions. I'm looking for eye-catching artwork for *Ham Radio* covers. Do you have a picture of an interesting Amateur Radio event, a wild looking antenna, a ham shack with a difference? Do your talents run to drawing or cartooning? Why not let us take a look at your work and see if it has the makings of a good cover piece?

Here are the basics. For those submitting photos, we prefer large-format transparencies or slides taken with 120 film. Shots taken with 35 mm film are sometimes usable, but often are not sharp enough when blown up to cover size. For those submitting drawings, colorful ones are best. But a dramatic black and white picture could also have possibilities.

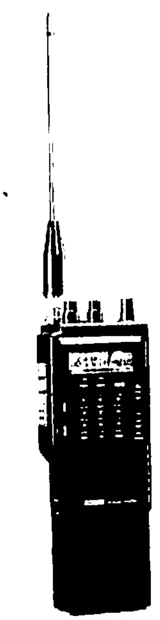
Don't be shy. Send us what you've got. Hans Evers, PAØCX, a favorite *Ham Radio* artist, was discovered when he included a doodle at the bottom of a manuscript he sent us. Could you be next?

Terry Northup, KA1STC

New Dual Band HT

Kenwood offers the TH-75A Dual Band HT which features:

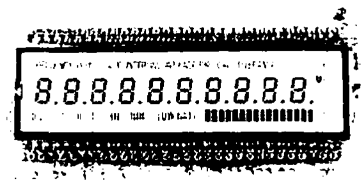
- Dual Watch function
- 1.5 watts on 2 meters and 70 cm: 5 watts when operated on 12 volts DC (or PB-8 battery pack)
- Large dual multifunction LCD display
- 10 memory channels for each band
- Selectable full duplex operation
- Extended receiver range
- Uses the same accessories as the TH-25AT (except soft cases)
- Volume and balance controls, plus separate squelch controls on top panel
- CTCSS encode/decode built in
- Automatic Band Change (ABC)
- Automatic offset selection on 2 meters
- Tone alert system for quiet monitoring
- Automatic battery saver circuit extends battery life.
- Supplied accessories:
  Dual band rubber-flex antenna, PB-6 battery pack, wall charger, belt hook, wrist strap, water resistant dust caps.



See your nearest Kenwood authorized Amateur Radio dealer for more details or write. Kenwood USA Corporation, PO Box 22745, 2201 E. Dominguez Street, Long Beach, California, 90801-5745. Suggested retail price: $549.95.

Universal Timer Counter Module/Panel Meter

Optoelectronics Inc has introduced a new ten-digit universal counter/timer module with direct frequency response from 0.1 Hz to over 150 MHz. There are up to nine digits of resolution per second. Functions include frequency, period, period average, time interval, time interval average, ratio, prescale, over range, and a 16-segment analog input bar graph.



Module size is 1.8" high × 3.55" long × 0.6" wide, suitable for OEM use in custom instrumentation or in a digital panel meter application. The ten-digit 0.25" character height LCD display has annunciators for function, gate time, range, measurement units, input A/B, low battery, prescale, and 16 bar graph segments.

Other features include an on-board 1 ppm 20 to 40 degree C 10-MHz timebase with calibration adjust trimmer, LCD contrast control pot, CMOS counter inputs (400 mV sensitivity typical), gate light LED, and an eight-bit A/D on board. Four countrol inputs are for momentary push buttons. The connector is a 14-pin dual 0.025" header. Power requirements are 5 volts DC, 50 mA. The module costs $225 in single quantities and $149 in hundreds.

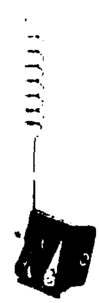
For details contact Optoelectronics Inc., 5821 N.E. 14th Avenue, Fort Lauderdale, Florida 33334. Phone (800)327-5912 or FAX (305)771-2052. In Florida call (305)771-2050.

Circle #305 on Reader Service Card.

"On-Glass"® Disguise Amateur Radio Antenna From A/S

The Antenna Specialists Company has introduced Model AP-143, an On-Glass disguise antenna for the 2-meter band. The new model uses the "pigtail" configuration of cellular antennas to hide the presence of professional radio equipment inside the vehicle.

The antenna's on-glass design, with capacitively coupled transmission through glass,



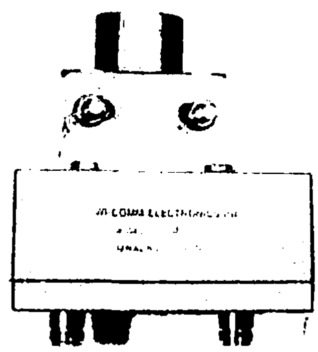
requires no ground plane and permits quick, no-holes installation. The 26-inch stainless steel whip is covered with a black DURA-COAT™ finish for long life. The antenna has a power rating of 100 watts continuous, 150 watts intermittent, and a VSWR of less than 1.5:1

For details contact The Antenna Specialists Company, 30500 Bruce Industrial Parkway, Cleveland, Ohio 44139-3996. Phone (216) 349-8400.

Circle #302 on Reader Service Card.

New Tower-mount Preamplifier

WI-COMM Electronics, Inc offers a new tower mount preamplifier in a weatherproof aluminum housing which covers the band from 10 to 900



(continued on page 53)

(continued from page 48)

MHz. The preamplifier gain is 25 dB, noise figure is 3.1 dB typical, 1-dB gain compression is at +10 dBm minimum, VSWR in/out is 2:1, and powering is +12 to 15 volts. Power is supplied via the output connector by a wideband DC block (bias tee). Standard connectors are type N female. Lightning static protection at the input and reverse polarity protection on the DC supply line are included. Wideband DC block is also available, along with the RX-RX switch (SPDT) and the amplifier bypass switch module (insertion loss 0.15 dB maximum, isolation 50 to 70 dB at 900 MHz, set time 5 ms, through power 10 watt maximum, powering +12 to +15 volts, and VSWR is 1.3:1 typical). The SPDT switch can be used to combine two antennas at the preamp input; the bypass switch module can be used to insert a pad/filter into the signal path.

For additional information contact WI-COMM Electronics, Inc., Box 5174, Massena, New York 13662. Phone: (315)769-8334.

Circle #307 on Reader Service Card.

Midland LMR Announces Data-Capable Syn-Tech™ Mobile Models

Midland LMR's new data-capable Midland Syn-Tech two-way FM mobile radios incorporate direct FM modulation (factory installed only) and are identified by the addition of a letter "D" suffix to the model number. They are the 110 watt 40-54 MHz models 70-052CD and 70-056CD (dash mount and trunk mount), the 40 watt 148-174 MHz models 70-340BD and 70-440BD, the 30 watt 450-470 MHz models 70-530BD and 70-630BD, and the 15 watt 800 MHz models 70-915D and 70-970D.

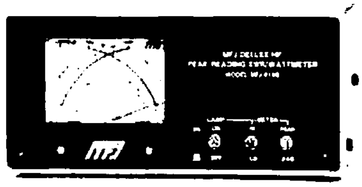
For more information contact Midland LMR, Marketing Department, 1690 N. Topping, Kansas City, Missouri 64120 or call 1-800/MIDLAND (1-800-643-5263), extension 1690.

Circle #304 on Reader Service Card.

New Function Added to MFJ-815B SWR/Wattmeter

MFJ Enterprises, Inc. offers a new peak reading function in the MFJ-815B lighted Cross-Needle SWR/Wattmeter for $69.95.

The MFJ-815B lets you monitor SWR, forward, and reflected power at a glance. You can select from two power ranges for forward and reflected power (2000 watts forward and 500 watts reflected or 200 watts forward and 50 watts reflected). It shows you SWR from 1:1 to 8:1.



The MFJ-815B covers 1.8 to 30 MHz with 10 percent accuracy. It comes with MFJ's full 1-year No Matter What™ guarantee. The meter light requires 12 volts DC or 110 volts AC with the MFJ-1312. The price is $12.95.

For more information contact MFJ Enterprises, Inc., PO Box 494, Mississippi State, Mississippi 39762. Phone: (601)323-5869.

Hamtronics New Computer-Controlled REP-200 Repeater

Hamtronics new REP-200 Repeater has all the features of their earlier units plus a microprocessor-controlled COR, CWID, autopatch, and DTMF decoder/controller with over 45 functions — including built-in testing features. It is available for 10, 6, and 2 meters; 220, 440, and 902 MHz; and for the high and UHF commercial bands.

The COR, CWID, DTMF controller, and autopatch are all on one board, along with new signal and power distribution circuitry. Four pc boards have been combined into one module, with IC sockets for easy service. Surface mount

capacitors are used in many places to reduce size and enhance performance.

Rugged welded RF partitions are an integral part of the compact new chassis, with Pem nuts to seal the covers for optimum shielding. The rack panel is only 3-1/2 inches high.

All interconnections are done through the controller board to eliminate cable harnesses. External cables for power, telephone monitor speaker, and auxiliary receiver are made with push-on terminals which plug directly into the controller board. There are more front panel indicators, color-coded LEDs indicate status of all major functions.

On the 2 meter and adjacent commercial band, a new 25-watt RF output option is available. In the unlikely event that isn't enough power for your application, you can add our accessory 100-watt PA. On UHF, choose from 10 watts with basic repeater or up to 65 watts with add-on PAs. On 900 MHz, choose 10-watt basic repeater or 40 watts with add-on PA.

For more information contact Hamtronics, Inc., 65-F Moul Road, Hilton, New York 14468-9535. Phone (716)392-9430, FAX (716)392-9420.

VHF/UHF Dual Band FM Transceiver from ICOM

ICOM introduces a new FM dual band mobile transceiver. The IC-2400A has independent frequency readouts and volume and squelch controls for complete dual band operation. Features include:

- High power output
- Full duplex capability
- 40 memory channels
- Two bands simultaneous receive

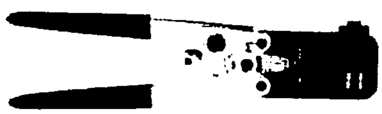
The IC-2400A uses ICOM's exclusive SET mode for simple operation. An optional PL tone encode/decode squelch pocket beep unit is also available. The suggested retail price is $899.

For details contact ICOM America, Inc., 2380 116th Avenue N.E., PO Box C-90029, Bellevue, Washington 98009-9029.

Circle #303 on Reader Service Card.

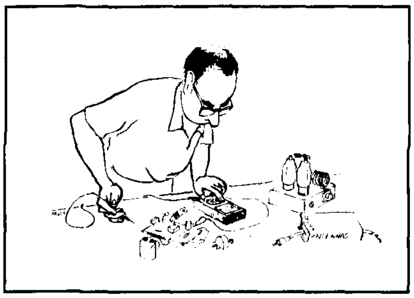
Handy New Tool from Nemal

Nemal Electronics International has introduced a new ratchet crimping tool. It offers full cycle ratchet operation with machined dies, and features a pin holder and wire locator. Part number CT2320 accommodates wire sizes from 20 to 30 gauge.



For additional information contact Nemal Electronics International Inc., 12240 NE 14th Avenue, North Miami, Florida 33161. Phone (305)899-0900 or FAX (305)895-8178.

Ham Radio Techniques



By Bill Orr, W6SAI

ANTENNA MATCHING SYSTEMS

Last month I discussed some unusual circuits capable of matching a coax line to a Yagi antenna. This column deals with an adaptation of the L-network, commonly called the "Beta" or "Hairpin" match. It's a simple and easily constructed matching device that any home builder can use with his beam antenna.

Generally speaking, the feedpoint impedance of a Yagi (regardless of the number of elements) falls between 15 and 25 ohms. The problem is to reach a reasonable match between these impedances and a 50-ohm coax line.

The picture is complicated by the fact that when matching is achieved at the design frequency of the antenna, it deteriorates when the antenna is operated off frequency. The L-network, however, is "user friendly" (low Q) and provides a good match across the HF Amateur bands, in spite of the impedance gyrations of the driven element. Some matching schemes will not do that.

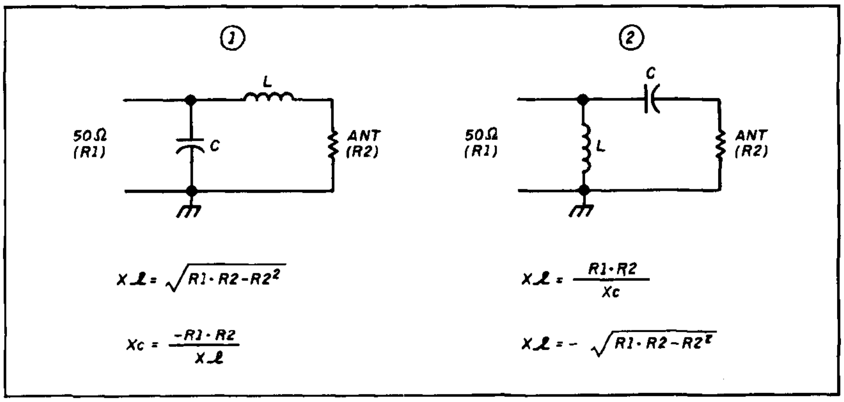
When the line impedance is greater than the feedpoint impedance of the antenna (as is the general case), the L-network takes the forms shown in **Figure 1**. Only two components are required — an inductor and a capacitor. It's possible to eliminate the series-connected component by making the driven element take its place. This is accomplished by detuning it slightly to introduce a value of series reactance equal to that of the missing network component. If the driven element is longer than the resonant length, its feedpoint reactance will be inductive (positive). If it's shorter than resonance, the reactance will be capacitive (negative). In this case, the shortened element will be used.

Because the feedpoint of the Yagi is balanced with respect to ground it's necessary to use a balun with the matching network, as shown in **Figure 2**.

Using the reactance match

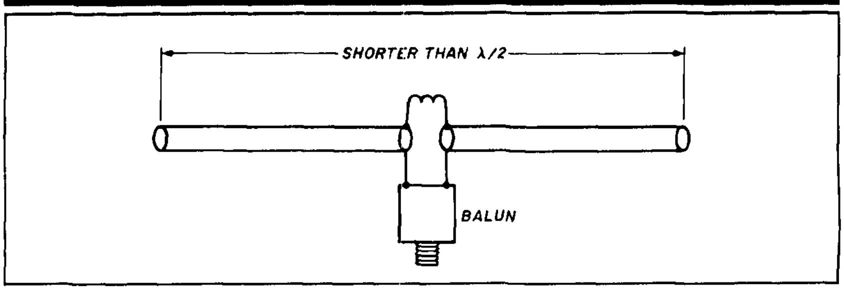
In most cases, the driven element of the Yagi is shortened to exhibit a series capacitive reactance. A shunt inductor provides the positive reactance of the proper value. The shunt inductor can be a coil, or it may be a "hairpin" of wire (see **Figure 3A** and **3B**). Most commercial beams using this matching scheme prefer the hairpin over the

FIGURE 1



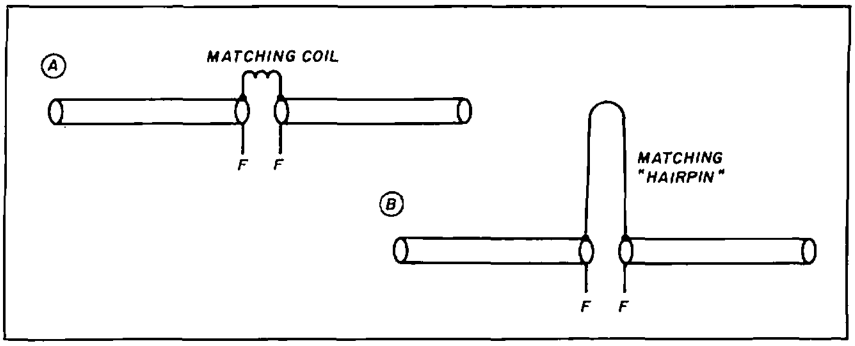
Basic single-ended L-networks to match feeline (R1) to antenna (R2) when line impedance is greater.

FIGURE 2



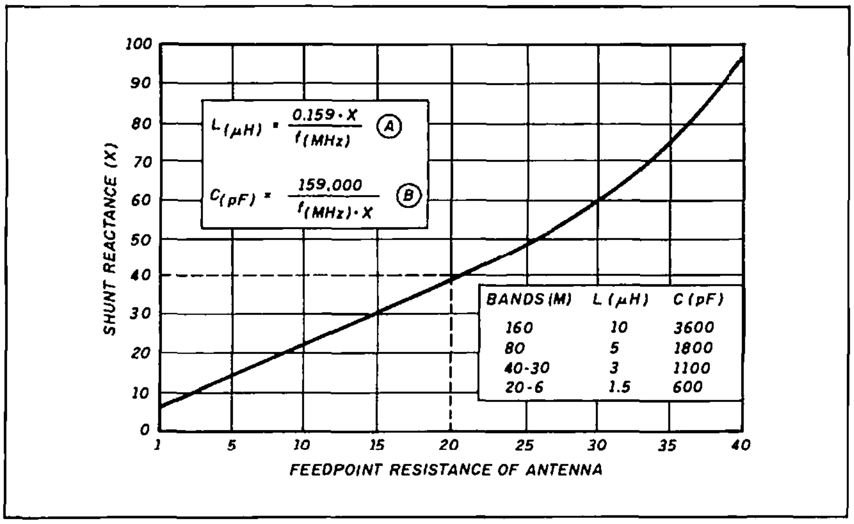
Balanced driven element is matched to coax by shortening it and using a parallel inductor at the feedpoint. A balun is used to match the antenna to unbalanced coax.

FIGURE 3



The shunt inductor may be either a coil or "hairpin."

FIGURE 4



Shunt reactance values required for various values of feedpoint resistance. Typical baluns are listed in the chart.

inductor because the inductance (length) of the hairpin can be adjusted easily. The two approaches are equally effective.

The homebrewer, on the other hand, may find the coil inductor easier to build than the hairpin. I prefer the coil because it's cheap, easy to wind, and can be adjusted at the center of the element — which is within easy reach from the top of the tower. (I don't like the idea of hanging out over open space to adjust the shorting bar on a hairpin match!)

In any event, the only adjustments you need to make in either system are to the length of the driven element and the inductance of the coil, or hairpin.

A practical matching circuit

The L-network parameters are summarized in Figure 4. The X-axis of the graph represents the feedpoint impedance of the Yagi driven element, and the Y-axis the value of shunt reactance necessary to achieve a match to a 50-ohm line.

For example, assume a Yagi has a feedpoint value of 20 ohms. The corresponding value of shunt reactance, as shown by the dashed lines, is 40 ohms. The actual inductance of the coil is determined by the formula. The driven element must be shortened, or "equalized," to provide the capacitive portion of the network.

Equalizing the driven element

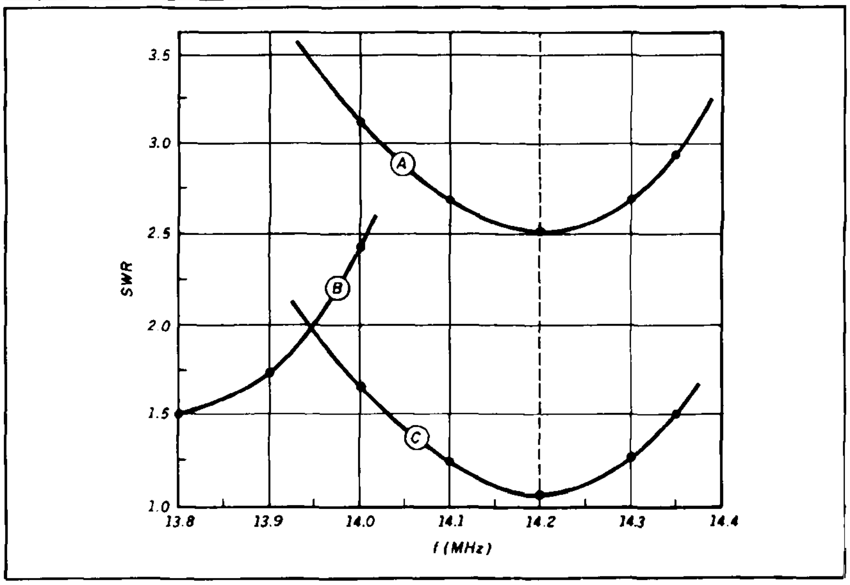
To make this matching system work, the driven element must be slightly detuned (equalized) to provide the necessary reactance at the feedpoint. What does this mean in practice?

By definition, when an antenna is detuned from one frequency it becomes resonant at another. For example, assume the driven element of a Yagi is resonant at 14.2 MHz, has a feedpoint resistance of 20 ohms, and you want to match it to a 50-ohm coax line. A frequency run of the antenna will resemble the SWR curve of **Figure 5**. At the resonant frequency, the minimum SWR value is 50/20, or 2.5:1. The SWR gradually increases as the antenna is operated off frequency (**Figure 5, curve A**).

A Beta match is used at the feedpoint to reduce the SWR. The correct value of inductance is determined from the table and an appropriate coil is placed across the feedpoint. An SWR plot of the antenna is run across the 20-meter band and compared with the plot run without the coil. The driven element and inductor combination are now resonant at 13.8 MHz instead of 14.2 MHz and minimum SWR is about 1.5:1 (**Figure 5, curve B**). Adding the matching inductor has lowered the indicated resonant frequency of the driven element by 400 kHz. Resonance is now outside the 20-meter band! The final step is to shorten the driven element to restore resonance at 14.2 MHz. Once you've done this, the minimum SWR at the resonant frequency will be very close to unity (**Figure 5, curve C**). Squeezing or expanding the coil turns a bit will drop the SWR curve "in the slot."

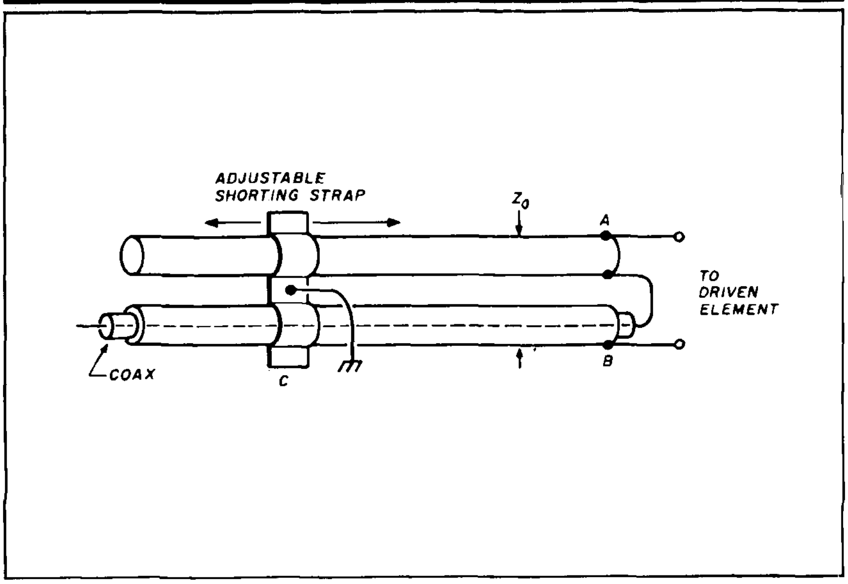
This procedure determines the correct length of the driven element indirectly, providing the required value of negative reactance at 14.2 MHz in order to make the matching system work as it should.

FIGURE 5



Curve A shows SWR with a feedpoint resistance of 20 ohms. Curve B shows the SWR with parallel inductance added. Curve C shows the SWR with the driven element equalized.

FIGURE 6



Matching balun is constructed by passing coax down inside of one leg. The inner conductor is cross-connected to the other leg at the balanced feedpoint.

Is equalization necessary?

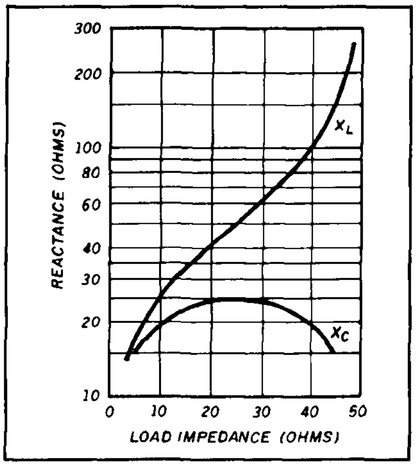
Equalization is necessary, especially with regard to solid-state transmitters that don't like to load into a transmission line having a high value of SWR. The amount of equalization required for the matching system to work depends upon the ratio of antenna feedpoint resistance to the coax line impedance. The greater the ratio, the more equalization (less coil inductance) required.

The problem is to determine the degree of shortening required to equalize the driven element. Very little information exists about the reactance change per unit of length for a Yagi driven element of a certain diameter. The reactance change is a function of frequency, element diameter, and taper. It generally amounts to a foot or more at 14 MHz, and correspondingly lesser amounts for the higher frequency bands. I challenge the readers of this column to come up with a computer program that relates reactance change of a half-wave element to the aforementioned parameters!

The adjustable Beta match

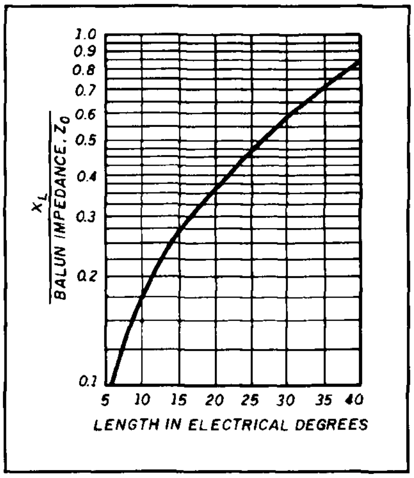
This relative of the hairpin match combines an adjustable impedance transformer with a balun. It's usable with antenna feedpoint impedances between 10 and 40 ohms. Basic operation follows that which is outlined for the hairpin match. The device is the parallel reactance portion of the L-network (**Figure 6**). The series reac-

FIGURE 7



Inductive and capacitive values for antenna equalization when 50-ohm coax line is used.

FIGURE 8



Electrical length of balun in degrees as a function of inductive shunt element (XL) to balun impedance (Zo).

tance is attained by shortening the driven element.

The network is converted to a balun as shown in the drawing. Points A and B of the linear balun are balanced to ground. The unbalanced coax line is brought into the balun through one of the balun tubes, with the center conductor of the coax crossing over at the antenna end of the balun to contact the opposite balun tube. This device provides both excellent balance and transformer action when you adjust the shorting bar at the opposite end of the balun and the length of the driven element.

Balance is achieved by permitting the outer shield of the coax line to assume the potential of the balun tube as it passes from the grounded end (C) to the terminal end (B). Cross connecting the center conductor to the opposite balun leg at A ensures the desired 180-degree phase reversal is achieved.

Once the transformation ratio and the values of series and parallel reactance have been determined, the balun is designed from transmission line formulas. The relationship between the balun parameters and the driven element is given in **Figures 7** and **8**. A plot of the ratio

$$\frac{Xl}{Zo}$$

in terms of line length for 20 meters is provided in **Figure 9**.

You can build a practical balun of 3/8-inch diameter thin wall copper tubing. A center conductor of RG-8A/U or RG-213 coax will just pass through the tubing when the braid and vinyl jacket have been removed. Using a center-to-center spacing of 3 inches for the tubes, you'll form a balanced line having a characteristic impedance of about 325 ohms.

Designing the Beta match

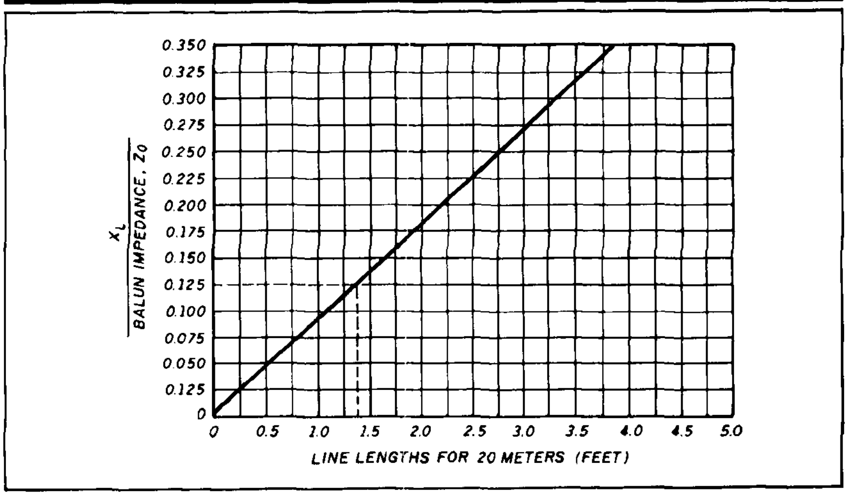
Assume the coax is 50 ohms and the Yagi feedpoint resistance at resonance is 20 ohms. In **Figure 7**, the value of Xc is −24.5 ohms and the value of Xl is 41.5 ohms **Figure 8** shows that the ratio of Xl to balun impedance is 41.5/325=0.127, as read on the Y-axis. The balun length, as read on the X-axis, is about 7.5 electrical degrees. To get the answer directly in feet, use **Figure 9** for the 20-meter band. In this example, the balun length is about 1.4 feet, or 17 inches, for a ratio of 0.127 (read on the Y-axis).

The series reactance value (Xc) of −24.5 ohms is achieved by shortening the driven element. It would be nice if this value could be computed, rather than determined by the heuristic (cut-and-try) technique. As I mentioned before, it's about a foot for 20 meters.

Elevated radials work! Good news for 160-meter DXers!

In my April and October 1988 columns I reported on the work of Doty, Adler, and others in computing and testing the practicality of using a few above-ground radials in place of buried radials, or a ground screen for low frequency vertical antennas. The May 24, 1989 issue of *Radio World*[1] reports that in November 1988 a full-scale AM antenna system was tested in Newburgh, New York under the direction of Clarence M. Beverage of Communication Technologies, Inc. The test frequency was 1580 kHz. The facility consisted of a 120-foot guyed tower with the base insulator 15 feet above ground. An elevated ground system consisting of six quarter-wave radials was used. The tests were conducted under a special field test authorization provided by the FCC.

FIGURE 9



Balun conversion chart for 20 meters. Balun length in feet may be determined if feedpoint resistance, shunt reactance, and balun impedance are known.

Field measurements run on the antenna showed that the radiated field was equal to that obtained from a 105-foot tower and a traditional ground system of 120 quarter-wave buried radial wires. The observed data confirmed theoretical data as computed through the use of a mathematical modeling technique called the "Method of Moments."

This is good news for low frequency operators partial to vertical antennas! The elevated radial system is thought to provide superior performance when compared with the buried ground system, because it allows the collection of electromagnetic energy in the form of displacement currents, rather than induction currents in the earth. In addition, the elevated ground system is less susceptible to changes in ground conditions caused by variation in moisture content in the earth.

It was determined that a frequency of 1200 kHz would require radial elevation of 20 feet and that 680-kHz operation would require elevation of 35 feet. Accordingly, 160-meter operation would allow a radial height of somewhat less than 15 feet. I hope the FCC will authorize the use of above-ground radials in the broadcast service quickly. Meanwhile, what are you waiting for? hr

REFERENCES

1. *Radio World*, a controlled-circulation publication of Industrial Marketing Advisory Services, Inc. 5827 Columbia Pike, Suite 310, Falls Church, Virginia 22041

✓ 132

✓ 130

✓ 131

AN INEXPENSIVE VFO

FOR THE YAESU FT-102

The basis of this circuit is a solid-state Franklin oscillator

By Robert H. Armstrong, VE3RF, 55 Birchview Road, Nepean, Ontario, Canada K2G 3G3

How would you like an external VFO for your Yaesu FT-102 that doesn't require any modifications or cost a small fortune? Mine uses the transceiver's digital readout, works on either or both transmit and receive, and drifts so little you'll need a frequency standard to measure it. Interested? Read on.

How it all started

In 1982 I bought a Yaesu FT-102 as a Christmas present (for myself). I got the AM/FM board and some crystal filters for CW and SSB, but I couldn't go the extra $500 or more for an external VFO. Not only was there not a "plain vanilla" VFO available, but the $500 one had memories, scanning functions, and a veritable calliope of bells and whistles. Besides, I couldn't see any real need for split frequency at that time.

Everything went beautifully until the 10-meter band started to open up this past year. I suddenly discovered that the 10-meter FM band required 100-kHz splits, and I didn't have that capability. I remembered an ad for the FV-102DM external VFO, which stated that the correct operating frequency was always displayed on the FT-102 digital readout. If I could do that I wouldn't need a fancy dial on the external VFO.

Fortunately, I had purchased a technical supplement for my FT-102 when they were available, although at the time I thought the price (about $25) was atrocious. Since then I've installed all the relevant mods, repaired the receiver preamp switch, and replaced a defective meter.

Digging into my supplements, I discovered the connections for the external VFO plug, and learned that I could indeed use the internal digital readout to display the frequency of an external VFO. This plug is an eight-pin DIN plug, type B (P1 in the schematic). There are two types of eight-pin DIN plugs. Naturally, according to Murphy's Law, I got the wrong one first. The correct plug is the nonsymmetrical one. (See **Figure 1**). Notice also that the pin numbering is not what one would consider normal — not me anyhow.

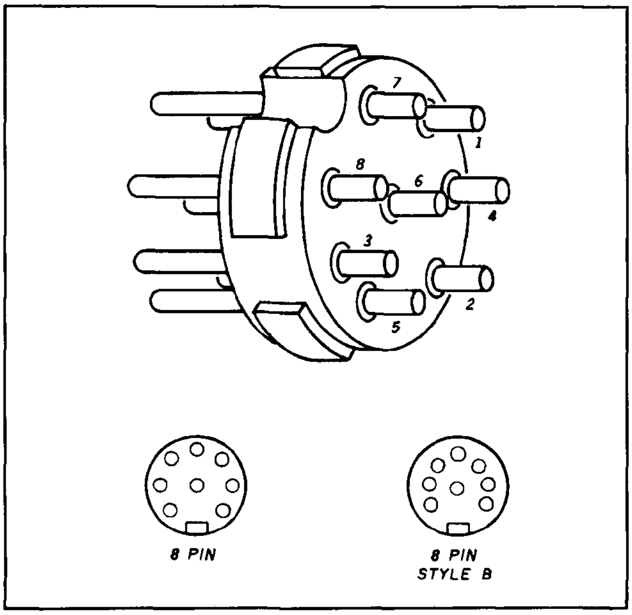
Developing the ideal VFO

Armed with all this technical information on how to connect the external VFO plug, I started looking for a suitable circuit. My ideal was preferably without coil taps, and certainly without parallel capacitors — too big to be *air* spaced, which could ruin the tuned circuit Q. I wasn't having much luck, until I came across the circuit for the Franklin oscillator in the *RSGB Handbook*. This is reproduced in **Figure 2A**.

The Franklin oscillator has no large capacitors paralleling the tuned circuit, and no taps on the coil. Only a pair of small coupling capacitors connects the coil to the oscillator circuit. It's an astable oscillator (multivibrator to us old-timers). The tuned circuit is in parallel with one of the crossed feedback lines, where it offers a high impedance across the line at the resonant frequency, and a low impedance at all other frequencies.

This looked interesting so I built an FET circuit on a protoboard, scaling the drain resistors to work with an 8-volt supply. The circuit is shown in **Figure 2B**. Note the similarity to the original tube circuit. I had to increase the coupling capacitors to 10 pF to ensure reliable oscillation at that voltage. This oscillator delivered 1.3 volts p-p at about 1000-ohms impedance. This was too high for the FT-102, which requires 200 mV p-p at 50 ohms. I followed it with a Darlington emitter follower to lower the impedance and a lowpass filter simi-

FIGURE 1



Eight-pin DIN plug showing pin numbering. Type B is the correct plug.

TABLE 1

Function of the pins of the FT-102 rear panel connector marked EXT VFO and RCVR — A.

This connector is an eight-pin DIN type B female connector. It is called J7 on the schematic diagram of the complete FT-102 transceiver, and is in the upper left corner of the diagram. Attached to pin 1 of J7 is an unlabeled DPDT switch. It operates when a connector is inserted into J7. It removes the 8-volt DC bias from the internal VFO signal, turning off the diode-switching circuit which normally accepts the internal VFO signal. If you plug a blank DIN connector into J7, the digital display blanks out. The 8-volt input to the internal VFO is connected to pin 1 of J7 when a connector is inserted.

J7 pin functions

1. Internal VFO enable input. Eight volts must be applied to pin 1 to enable the internal VFO when a plug is inserted.
2. Twelve volts output from the transceiver. The maximum available current is 300 mA.
3. Output, 500 kHz. Adds 500 kHz to digital display when required. An example is the 28.5 to 29-MHz band (not used).
4. TX 12 volts. Twelve volts is supplied to this pin by the transceiver in the transmit mode.
5. CW 8 volts. Eight volts is supplied to this pin by the transceiver in CW mode (not used).
6. External VFO input. Requires 200-mV p-p at 50 ohms impedance.
7. Chassis ground.
8. Sample of VFO input selected (not used).

lar to the one Yaesu uses for the internal oscillator The overall output is about 220 mV p-p at 50 ohms.

Power and control circuitry

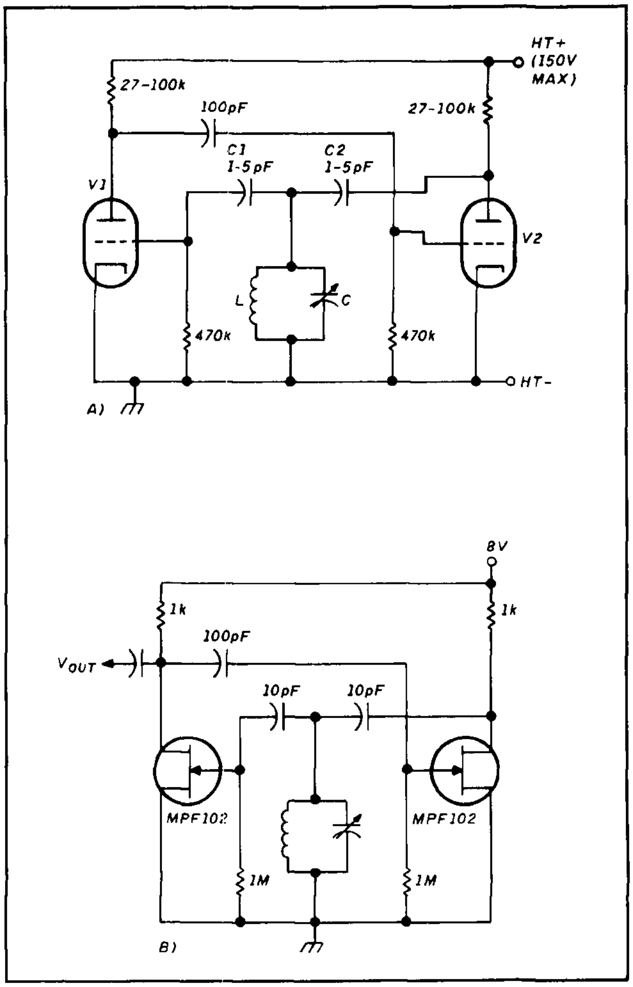
The VFO is powered from the FT-102. A 12-volt source is available on pin 2 of the external VFO connector (see Table 1). The VFO measured current is 55 mA, well within the available 300-mA maximum. A 7808 voltage regulator reduces the 12 volts supplied to the 8 volts desired. This is a bit of "overkill;" the 7808 will handle better than 1 A, so it doesn't need a heat sink. You can replace the 7808 with an LM317 adjustable regulator The LM317 may be easier to find, and requires only two external resistors to program it. This circuit is shown at the bottom of the schematic in Figure 3.

The FT-102 has another 12-volt output available on transmit only. This powers an SPDT relay which switches the 8-volt supply to provide both a receive-only and a transmit-only voltage. These switch the VFO diode circuits in the FT-102 and are selected with the front panel EXTERNAL/INTERNAL toggle switches. I could have done this with CMOS logic, but I had the relay on hand. The complete circuit of the VFO is shown in Figure 3.

Mechanical construction

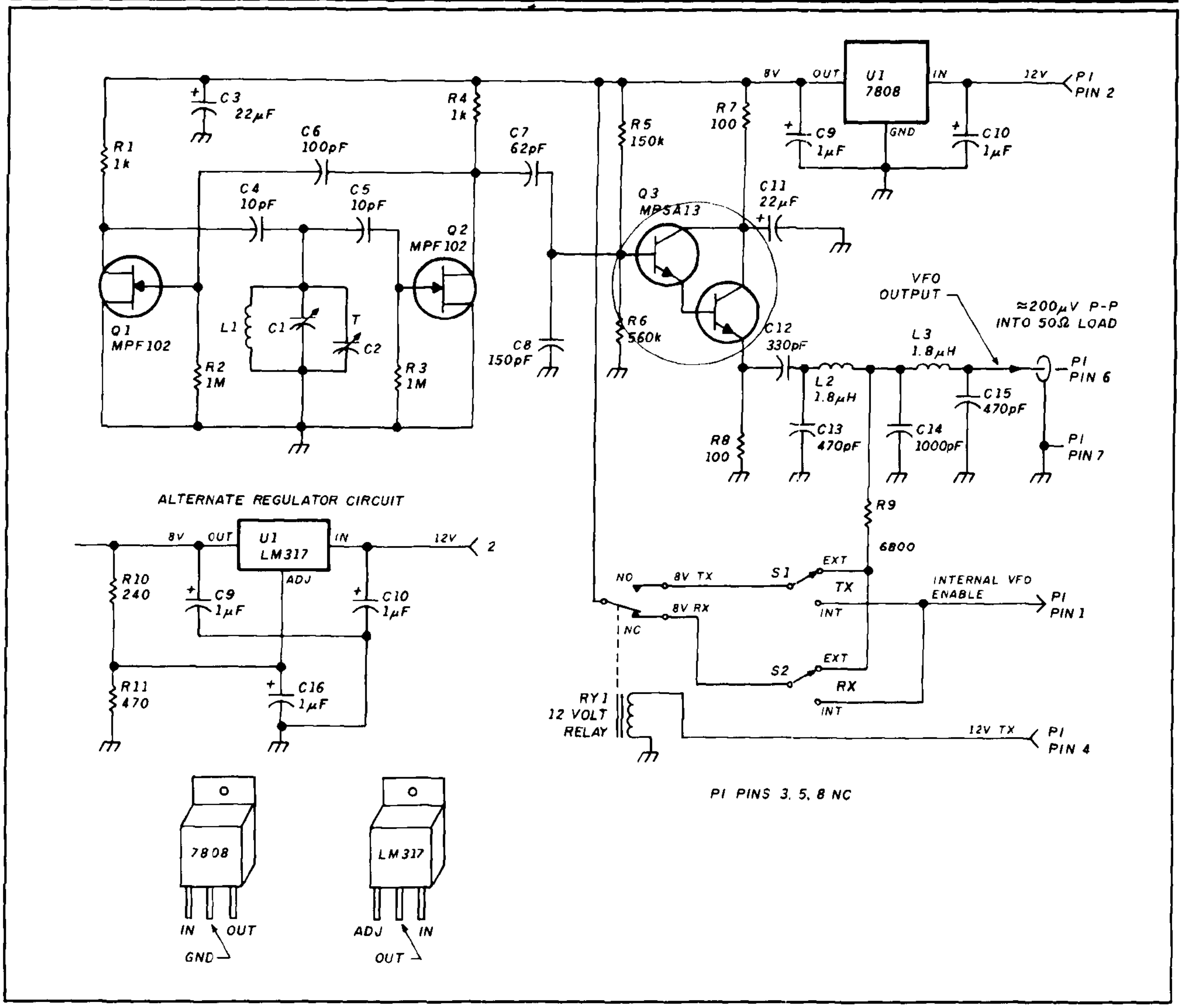
- Tuned circuits. Now that I'd designed the VFO, I had to build it. I measured a military surplus coil on a 1-3/8 inch

FIGURE 2



Original diagram of the Franklin oscillator reproduced from the RSGB Handbook (A). The same circuit modified for FETs is shown in B.

FIGURE 3



Schematic diagram for the FT-102 external VFO.

ceramic form; it had 6.8 μH inductance. I used an FM-tuning capacitor that had been in the junkbox for a couple of years. It had three sections which, when connected in parallel, produced 30-pF capacitance change. This enabled a frequency shift that exceeds the required 5.0 to 5.5-MHz VFO frequency range slightly. A 150-pF air-spaced, screwdriver-adjusted trimmer capacitor completes the tuned circuit.

- **Circuit board assembly.** Keeping as much room as possible around the coil, I mounted the tuning and trimmer capacitors in one end of the cabinet and assembled the electronic parts on top of them. I don't usually build pc boards for my projects as they are one-of-a-kind things. I used a universal circuit board and assembled this circuit at the right side of the cabinet. You don't need to take any special precautions. Just be sure to make the assembly as mechanically stable as possible.
- **Reduction gear and tuning capacitor.** One aluminum bracket holds the 3:1 reduction gear for the dial; another ties from this to the back of the case as a support for the tuning capacitor. I bent both brackets to fit the cabinet by hand and assembled them with nuts, bolts, and lockwashers. My leads are as short and direct as possible. All ground leads in the oscillator circuit are connected to a common ground at the frame of the tuning capacitor. I used an insulated coupling between the tuning capacitor and the dial to avoid hand capacitance effects. The coil is raised to the center of the clear space with spacers, in keeping with the idea of having everything clear of the coil by a distance at least that of the coil diameter. This is necessary to obtain a high-Q tuned circuit.
- **Dial readout.** If you look at **Photo A**, you'll notice that the dial reads backwards. This is because the VFO frequency is subtracted from other frequencies in the FT-102. If you have a double shaft tuning capacitor, arrange it to have maximum capacitance at the clockwise end of the dial. This will make it read forward. The dial consists of a paper scale behind a plastic plate. The

PARTS LIST

Capacitors	
C1	*Tuning capacitor, should be air spaced, approximately 50 pF maximum (see text)*
C2	*Trimmer capacitor, air spaced, 150 pF maximum*
C3,C11	*22-μF tantalum, 10 volts*
C4,C5	*10-pF silver mica*
C6	*100-pF mica preferred, ceramic otherwise*
C7	*62-pF mica or ceramic (see text)*
C8	*150-pF mica or ceramic (see text)*
C9,C10,C16	*1-μF tantalum, 10 volts, Radio Shack 272-1434*
C12	*330-pF mica or ceramic*
C13,C15	*470-pF mica or ceramic*
C14	*100-pF mica or ceramic*
Inductors	
L1	*6.8 μH, 16 turns of no. 16 tinned copper wire on 1-3/8 inch diameter ceramic form, coil length 1-1/8 inches*
L2,L3	*1.8 μH, 13 turns of no. 24 enameled wire on FT 50-61 core.*
Resistors (all ¼ watt)	
R1,R4	*1000*
R2,R3	*1 meg*
R5	*150 k*
R6	*560 k*
R7,R8	*100*
R9	*6800*
R10	*240, R10 and R11 required only if LM317 voltage regulator is used*
R11	*470*
Miscellaneous	
Q1,Q2	*MPF-102 or 2N3819 N-channel JFET, Radio Shack 276-2035*
Q3	*MPSA30 Darlington transistor, Radio Shack 276-1631 is an assortment of six Darlingtons*
U1	*7808 voltage regulator, substitute LM317 (see Figure 4), LM317 is Radio Shack 276-1778*
RY1	*SPDT contacts, 12-volt coil, Radio Shack 275-241 or 275-213 (DPDT)*
S1,S2	*SPDT toggle switches, Radio Shack 275-625*
P1	*Eight-contact DIN plug (type B), Armaco type DD 8281 (should be available from Yaesu as a replacement part for the FV-102DM synthesized VFO), Yaesu USA, 17210 Edwards Road, Cerritos, California 90701.*

The cable to the P1 plug requires one shielded and three unshielded leads. I made it about 2 feet long.

The cabinet I used is a Hammond type 1426KB. It measures 4" high by 6" wide by 5" deep. You can order this cabinet from: Hammond Manufacturing Company, 394 Edinburgh Road, Guelph, Ontario, Canada N1H 1ES, or 1690 Walden Avenue, Buffalo, New York 14225

pointer is a no. 16 tinned copper wire attached to the vernier drive mechanism.

- External VFO calibration. Toggle switches S1 and S2 select either internal and/or external VFO for transmit and receive. It's only necessary to provide rudimentary calibration on the external VFO. I placed only the 100-kHz marks on the dial for frequency selection, as the exact frequency is displayed on the FT-102 digital readout. See Photos B and C for internal parts placement.

Parts substitution

If you're like me, you'll want to change a few things. Very few of the parts are critical. Perhaps the most important are the two 10-pF capacitors that couple the frequency-determining tuned circuit into the oscillator. These should be the best capacitors you can get. I used silver mica, but ceramic disc capacitors would probably do. The tuning capacitor and trimmer are both air-spaced capacitors; nothing less should be used for these. I used tantalum bypass capacitors because they are good high frequency caps. The 1-μF capacitors at the regulator should be mounted as close to the regulator as practical because the regulator contains a high gain amplifier that will oscillate if not well bypassed.

I wound L2 and L3 on ferrite cores salvaged from a Jerrold CATV amplifier. Realizing that these wouldn't be reproducible, I got an FT50-61 core and wound another on it. It required 13 turns of no. 24 enameled wire for 1.8 μH. The universal pc board I used is similar to Radio Shack's 276-158.

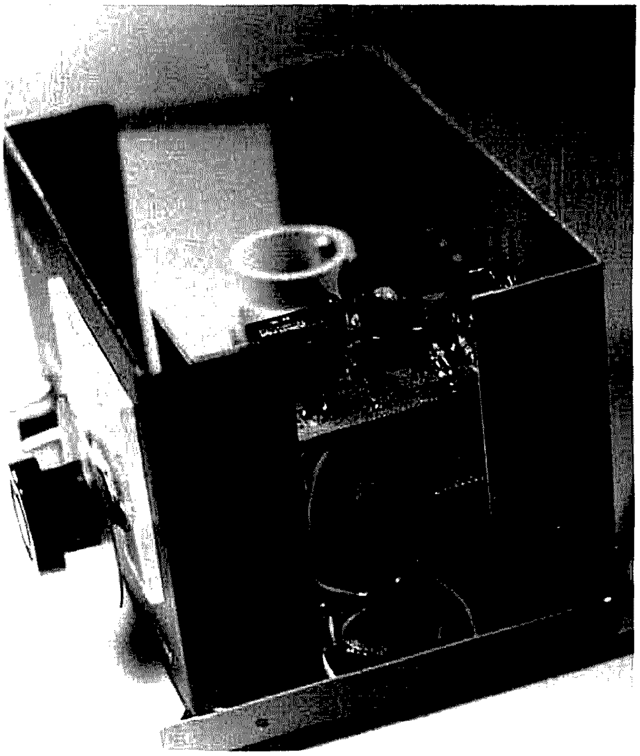
PHOTO A

Front view of the VFO with the cover removed showing the DIN plug and the circuit diagram inside the lid.

PHOTO B

Left-side view of the VFO showing component placement.

PHOTO C



Right-side view of the VFO showing trimmer capacitor mounted at rear of cabinet.

Testing and calibration

The two capacitors at the oscillator output (C7 and C8) form a voltage divider to reduce the oscillator output. Make C8 larger if you have too much output, or smaller if there's too little output. Measure the output at pin 6 of the DIN plug, loaded with a 50-ohm resistor, or plugged into the FT-102. It should be approximately 200-mV p-p.

Calibration is simplicity itself. Warm up the FT-102 on the 40-meter band with the external VFO attached for at least five minutes. Switch the RX switch on the VFO to the external position and set the tuning capacitor to maximum capacitance. Adjust the trimmer until the FT-102 digital readout reads slightly lower than 7000 kHz. Tune the VFO to the other end of its dial. The frequency should read slightly more than 7500 kHz. A reading lower than this would indicate that there's not enough variation of capacitance in the tuning capacitor; a much higher frequency would means there's too much variation. Mine tunes from 6955 to 7525 kHz. You could also use a digital frequency counter to read the frequency.

Remember that it's backwards, so a VFO frequency of 5500 kHz corresponds to 7000 kHz, and 5000 kHz corresponds to 7500 kHz. If your counter requires more than the 200 mV at the output, there's more than 1 volt available at the drain of Q2 — although the counter may change the oscillator frequency by a few hertz.

When you've finished your work, but before you button up the cabinet, glue a schematic diagram inside the lid of the case. In five years time, you'll have forgotten all the circuit details and will need the diagram for servicing.

COLLAPSIBLE QUAD FOR 10-METER HILLTOPPING

By L. B. Cebik, W4RNL, 2414 Fair Drive, Knoxville, Tennessee 37918

Ten meter activity is at a peak and the availability of small rigs like the HTX-100, the President, and the Ranger make wilderness portable operation more interesting than ever. Of course the weak link in the system is almost always the antenna. Mobile antennas are inefficient. Beams are too large for easy transport, even when they're broken down. Dipoles have to be hung. This usually means mounting them low to the ground, unless someone is willing to climb a tree.

The collapsible one-element quad described here provides most of the features hilltoppers want in an antenna:

- The quad loop shows high efficiency and, as a bonus, relative immunity from the effects of surrounding objects.
- Even at a 10-foot elevation, the quad shows a good bidirectional pattern.
- The antenna width is less than 9 feet and ideal for erecting in tight spaces (like between two cars).
- The antenna goes from storage to use (and back again) in less than 10 minutes — including rig tune-up.
- The quad collapses without disassembly into a package about 8″ × 6″ × 5-1/2 ′ for easy transport.
- Except for a female coax connector (SO-239) and a scrap of plastic, all parts for the antenna are available from the hardware store.

Electrically there's nothing new in the collapsible quad. It's cut to the textbook formula that defines the quad's length in feet as 1005 divided by the frequency in megahertz. With a target frequency of 28.5 MHz, the overall loop is about 35-1/4′ long or about 8′9″ on a side. A quad loop at least a half wavelength above ground has a feedpoint impedance of about 120 ohms, a factor I'll discuss later.

Building the collapsible quad

The traditional way to build a quad is to use an X support with a single piece of wire around the perimeter. The hilltopper uses a different mechanical scheme. As **Figure 1** shows, the antenna uses a PVC center support, aluminum L-stock horizontal elements, and wire vertical elements. The PVC pipe mounts over standard TV masts.

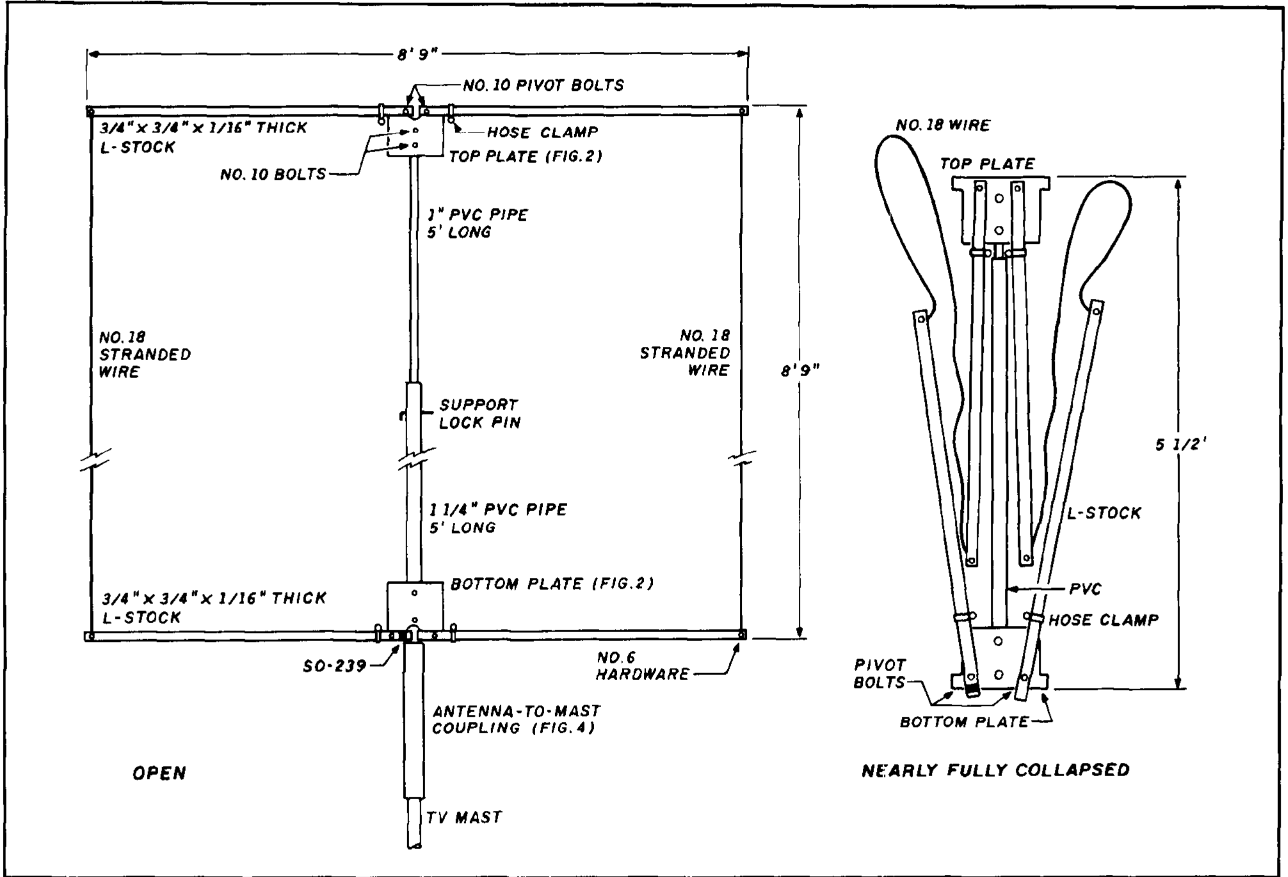
The PVC center support consists of two 5′ pieces of rigid PVC plumbling pipe. The top piece is 1″ diameter; the bottom piece is 1-1/4″ diameter. This gives you an outside diameter of 1-5/16″ for the top piece and an inside diameter of 1-3/8″ for the bottom piece. They nest easily and loosely.

Mount an acrylic plate cut to the dimensions shown in **Figure 2** on each PVC section. A pair of no. 10 bolts and nuts per plate provide more than enough strength to hold the plates securely. I cut my plates from 3/16″ scrap taken from a protector designed to go under an office chair. Use care when cutting the 1″ × 3/4″ wings to prevent stress cracks. Drill a small (1/8″ to 3/16″) hole at the inside corner and then cut to the corner. If you use a sabre saw, work slowly to prevent the hot plastic chips from binding the cut closed.

Drill the plate-to-PVC holes about 1-1/2″ from the top and bottom of the plate. Drill holes for no. 10 hardware which will form the pivot points for collapsing the antenna elements in line with the wings. One-inch hose clamps slip over the L stock elements and onto the plastic wings to lock the horizontal elements in place. Squeeze the clamps to partially shape them to the odd element configuration.

Because each horizontal element is 4′ 4-1/2″ long, use 4 pieces of 3/4″ × 3/4″ × 1/16″ thick aluminum L stock. I used 8′ sections (Ease, Inc. no. 2207) and have enough left over for a 6-meter quad loop. Mount each element to the plate with no. 10 hardware, leaving a 1/8″ gap between them. Make a bridge piece for the top section from no. 18 wire, ring connectors, and no. 6 hardware. Note the orientation of the L stock. The flat side of the L should face toward the center of the antenna, not outward. This provides good strength in the direction of tension from the side wires.

At the center of the bottom element, use a chassis punch



Overall view of the quad loop, open and collapsed.

to cut a 5/8" diameter hole in one of the pieces for a modified SO-239. Be sure to leave enough room between the SO-239 threads and the L stock wall for the screw-on sleeve of the male connector. Cut off two opposing mounting hole corners from the female coax connector and file the cut edges smooth. Using the two remaining mounting holes, mount the connector to one side of the bottom horizontal element. On the prototype the connector is outside the no. 10 pivot hardware. If you widen the pivot points on the bottom section plate, there may be room to mount it close to the center gap between the two element pieces. Drill the other L stock section at the gap for no. 6 hardware. Make a no. 18 wire bridge and put a ring connector on one end. Solder the other end to the coax center pin.

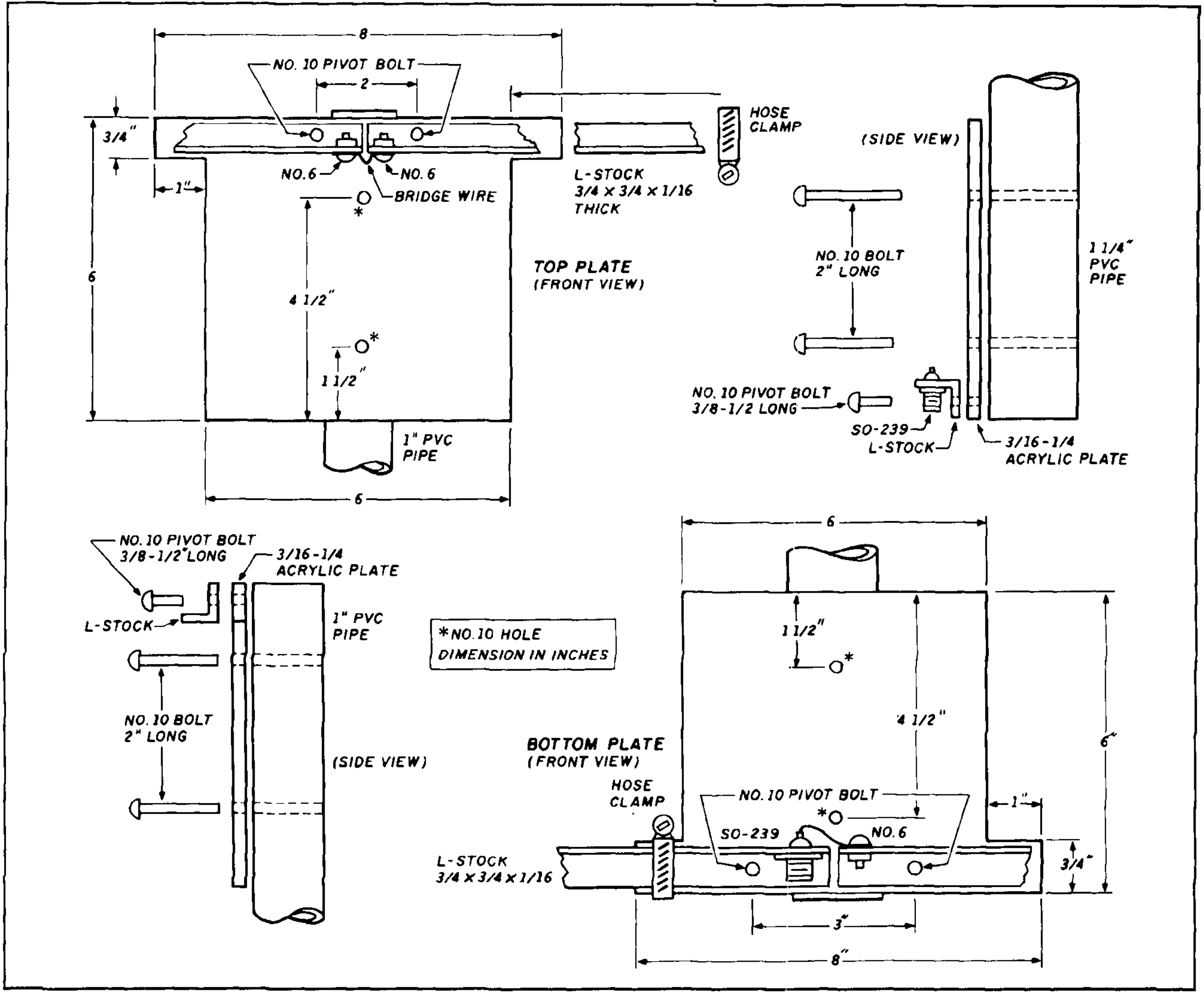
Cut two pieces of wire (no. 18 insulated stranded wire works well), each 8'9" long. Solder ring connectors to each end. Drill the vertical side of the L stock at each corner for no. 6 hardware. Be sure the hose clamps are attached to the four pieces of L stock. Slide the top PVC section inside the bottom section, then connect the vertical wires to each side.

To complete the basic antenna, drill a hole through the two PVC sections at the center Lay the antenna on a flat surface like a driveway or a basement floor. Extend the horizontal elements and lock them by tightening the hose clamps over the wings and securing the pivot hardware.

PARTS LIST

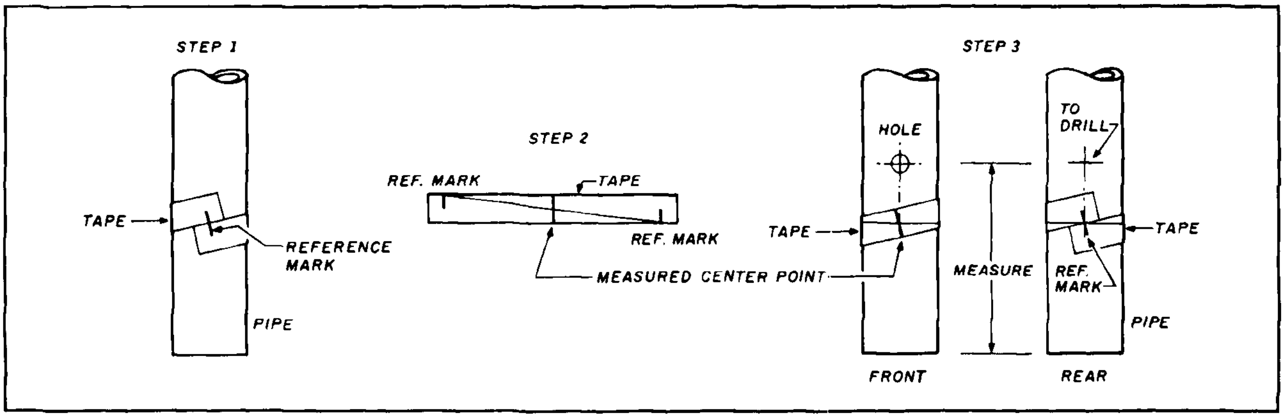
Number Rquired	Item	Source
4	*3/4" x 3/4" x 1/16" thick aluminum L stock (angle stock), each piece at least 5' long*	*hardware store*
4	*stainless steel hose clamps, 1" diameter*	*hardware store*
2	*acrylic plates, 3/16" (or more) thick, 6" x 6", with 3/4" x 1" wings*	*scrap*
18'	*no. 18 stranded copper wire, insulated*	*Radio Shack*
1	*5 feet of 1" PVC-1120 rigid pipe*	*hardware store*
1	*5 feet of 1-1/4" PVC-1120 rigid pipe (Note: small additional lengths are needed for the antenna-to-mast coupling described in the text.)*	*hardware store*
5	*no. 10 bolts, at least 2" long, with nuts*	*hardware store*
4	*no. 10 bolts, 3/8" long, with nuts (pivots)*	*hardware store*
7	*no. 6 machine screws, 3/8" long, with nuts*	*hardware store*
2	*no. 4 machine screws and nuts for coax connector*	*hardware store*
7	*ring connectors*	*Radio Shack*
1	*SO-239 female coax connector (modified)*	*Radio Shack*
2	*5 foot TV masts*	*Radio Shack*
1	*1-¼" inside diameter crutch tip*	*hardware store*
45'	*1/8" to 3/16" diameter rope*	*hardware store*

FIGURE 2



Top and bottom acrylic plate detail.

FIGURE 3



A simple method for drilling PVC pipe.

Extend the PVC sections until there's light tension on the L stock as the wire side elements reach their limit. Mark the inner pipe at this point. Make a vertical alignment mark on both pieces so the final product will be a flat plane.

Drill a hole through both pipes to fit a bolt or other pin. I use an old L-shaped Allen wrench a bit over 1/8" in diameter. Using a drill press will assure that you'll have well-centered holes. For free-hand holes, drill through one side of each PVC pipe only, preferably at the alignment mark. Using the larger pipe, wrap a piece of masking tape around the pipe at a slight angle so that the left edge of one end meets the right edge of the other, as shown in **Figure 3, Step 1**. Make a mark across the two edges. Remove the tape and spread it on a plate. Measure the exact center between the two marks, as shown in **Step 2**. Now follow **Step 3** and replace the tape, aligning the center mark with the first hole you drilled. The drill line is where the other marks meet on the other side of the pipe. Measure the distance from the pipe end of the first hole and mark an equal distance on the reverse side. The cross hairs mark the point to drill. Use a very short bolt to hold the first inner and outer holes together and drill through the second outer hole to complete the passage for the pin.

Opening and closing the completed antenna

Place the completed antenna on the floor to practice opening and closing. To open the antenna for use, bring each L stock element to the horizontal. Slide the hose clamps over the plastic plate wings and tighten. Tighten the no. 10 pivot hardware. Make sure the no. 6 hardware is secure at the wire ends and bridge connections. Extend the nested PVC pipe section until the center holes are aligned and plug in the pin. All that remains is to connect the coax and put the antenna on a mast.

Reverse the process to collapse the antenna for transport and storage. Assume that you have removed the coax and dismounted the antenna from its mast. Loosen the hose clamps and slide them off the wings. Loosen the no. 10 pivot hardware and swing the horizontal elements to align with the PVC pipe. Remove the pin through the pipes and nest the sections together as far as they will go (to the plate bottoms). Use the side wires, tie wraps, or other binders to wrap each end of the collapsed assembly. The antenna is now ready for transport.

Mounting the antenna

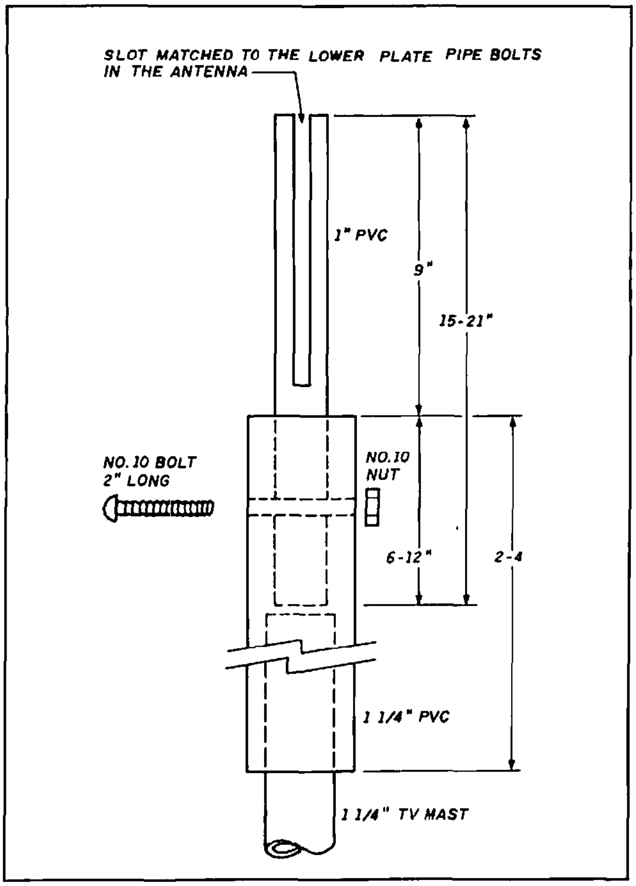
Mounting the antenna to a mast requires a bit of thought and preparation. There are undoubtedly many schemes that will work. For hilltopping, I use two 5' sections of TV mast to elevate the bottom of the antenna 10 feet off the ground. I keep the swaged end of the masts down and have installed a crutch tip to the end that touches the ground to keep dirt out of the mast. I can use up to two more sections with simple rope guying.

The mast-to-antenna support section shown in **Figure 4** serves two purposes. The slotted upper section of 1" PVC fits over the bolts that hold the plate to the bottom section of antenna PVC. The 9" slot holds well for hilltop operations, but wouldn't be suitable for taller masts subject to higher winds.

The 3' length of 1-1/4" PVC slips over the top of the TV mast. It's long enough to provide a secure mount and to allow redirection of the antenna by the "armstrong" method. Because the antenna shows a bidirectional pattern, even when close to the ground, it's important to be able to turn the antenna 90 degrees. You can add a rubber grip or handle to the bottom end of the PVC for easier turning.

Guying is simple with just 10 feet of mast. I loop three 15 foot 1/8" ropes over the top of the bottom plate. This anchors the antenna to the mast in light breezes. If the antenna is mounted between cars, I make loops to hold bungee cords hooked to fender wells or door handles. On open ground I tie the guy ropes to metal tent pegs. My YL, N4TZP, and I can assemble and erect the entire system

FIGURE 4



Mast-to-antenna support section.

in 10 minutes as nothing weighs more than about 5 pounds. Higher installations require more elaborate systems using guy rings and secure fastenings.

My simple mounting and guying system has survived 15 mile-per-hour breezes without difficulty. Anything above that level would kill my urge to operate on a hilltop, anyway.

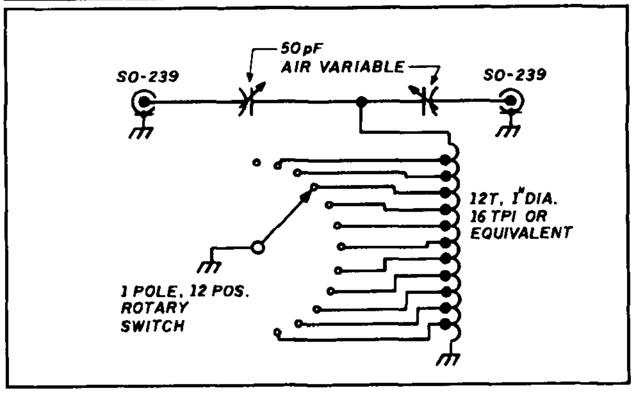
Tuning the antenna

A quad can't resist the offset of its normal feedpoint impedance close to the ground. At heights above a half

wavelength, the quad norm of 100 to 120 ohms permits the use of a simple matching section with 50-ohm output transmitters. A 5′7″ length of RG-59 will perform the transformation. At lower heights, however, the section becomes useless.

Because the coax (RG-58) is only about 20 feet long its losses with a low power rig are small, even with SWRs above 3:1. This is why I use the simple homebrew T-circuit matching unit shown in **Figure 5**. The capacitors are 50-pF MAPC types with shafts. The coil is 12 turns of 1″ diameter, 16 turns-per-inch miniductor type stock. A 12-position switch taps the coil at each turn. The tuner is in a 4″ × 5″ × 6″ aluminum case salvaged from another project, but a smaller case would work. I keep an old SWR meter attached to the tuner with a double male connector. Tune-up is a quick process because my HTX-100 has a 5-watt output position, and there's a high safety margin if the initial settings are way off base. I have the quad settings marked on the case. Changes of location require only the smallest tweaking of the capacitors to eliminate reverse voltage readings.

FIGURE 5

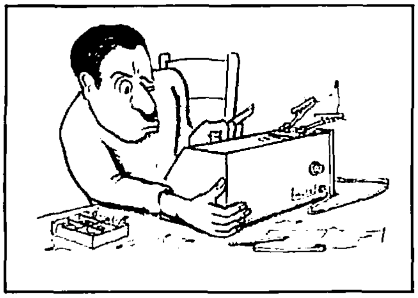


Simple T-match circuit for the collapsible quad.

The proof of the system is in the operation. A recent trip to Signal Mountain, Tennessee, to participate in the Chattanooga Choo Choo Net, produced excellent results. The W4RNL/N4TZP station (with the assistance of WA4TKN) received excellent signal reports. We could work almost everything the big beams on the mountain could. By pointing northeast-southwest toward Knoxville (120 miles away) we heard WA4TJW check out due to local thunderstorms. Turning more east-west brought a number of W5's to workable levels. The station went from car to on-the-air in 10 minutes (including setting up a small table with folding legs). After the session it took us 10 minutes to load the antenna back into the car.

Experiences like these have confirmed the soundness of developing a hilltop antenna which is more efficient than the usual mobile whip, and more free-standing then the usual dipole. The collapsible quad loop inexpensively fills a gap in the range of antennas available for portable 10-meter operations. ■

Practically Speaking



Joseph J. Carr, K4IPV

TEST EQUIPMENT FOR DIGITAL ELECTRONICS

In the past the Amateur operator with a technical bent dealt exclusively with what today is known as "analog electronics," i.e., RF, audio, and control circuits. But the digital revolution has touched Amateur Radio too, bringing us computerized and digitized ham gear. The modern HF transceiver is microprocessor controlled, as are many other bits of Amateur equipment. In this month's "Practically Speaking" I'll look at digital test equipment and highlight an affordable logic analyzer.

Once you get above the complexity level of a few chips, digital systems become quite a bit harder to "wring out" on the bench. It's difficult to service or analyze digital computer hardware because it's hard to get a good look at circuit operation as it sequences through its routine. Many things happen simultaneously — too many things to view on a simple oscilloscope (even a four-channel model). Sometimes you must view a large number of sequential operations (and their results) to find a problem. It might also be necessary to examine a data stream to determine what's actually going on. The logic analyzer provides the solution to these problems. This instrument examines multiple logic lines simultaneously and reports on their status. Until recently, logic analyzers have been expensive instruments and somewhat beyond the reach of most people. The Heath Company now offers equipment that may help. Although the company is recognized by most Amateurs for its kit-built ham gear and low cost test equipment, Heath also makes a considerable line of digital instruments and the Heath/Zenith line of personal computers.

The Heathkit IC-1001 shown in Photo A is a kit-form digital logic analyzer with a surprising number of capabilities. It can examine and report digital logic activity on up lo 16 digital input lines simultaneously. This capacity is sufficient for most 8 and 16-bit microcomputer applications. The IC-1001 is an inexpensive box that interfaces with any Heath/Zenith terminal or any IBM PC compatible. You need special software (included) to use an IBM PC as the terminal (DOS 2.0 or higher required). The interface to the terminal or the computer is via an RS-232 (DB-9 connector style) asynchronous serial communications port.

PHOTO A

The Heathkit IC-1001 Logic Analyzer.

The IC-1001 has 2K of RAM and can store up to 2046 16-bit binary words. If you use a terminal unit, you can display 24 words at a time. If you use an IBM PC, the monitor will display up to the entire 2046 memory simultaneously. Displays include: address relative to trigger word, state, timing, hexadecimal or octal equivalent, and ASCII equivalent. All the standard baud rates used in personal computer applications (as well as most other digital applications) can be accomodated: 300, 600, 1200, 2400, 4800, 9600, and 19200 BAUD.

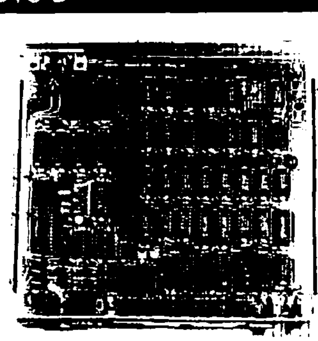
Under program control, you can specify the target trigger word that the IC-1001 is to recognize. The logic polarity (positive logic is normal, but you sometimes find negative logic) is selectable. There are also two modes — non-delay and delay. In the non-delay mode the analyzer will display data that occurred both before and after the trigger word (selected by the operator). In delay mode, you select the number of "qualifying clocks" that must occur following the trigger word before the IC-1001 starts storing the received data. Up to 50,000 clock cycles can be programed into the delay mode.

Construction

The IC-1001 Logic Analyzer is a kit. An experienced kit builder can put it together in one day or two evenings. The layout (shown in Photo B) is very clean and easy to work with. The kil is built on a single pc board mounted in a 1.75 × 9.25 × 8.5 inch lowboy cabinet. An external transformer plug supplies power to the IC-1001 from the 115-volt AC power lines. The unit weighs just 2.9 pounds.

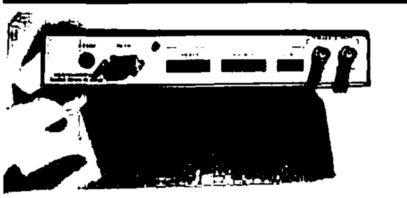
Because the IC-1001 is a newer Heathkit, the small parts (resistors, diodes, etc.) are attached to a paper "machine gun" belt in the sequence called for by the instructions. (Heath used to jumble everything together in brown paper bags for you to sort out.)

PHOTO B



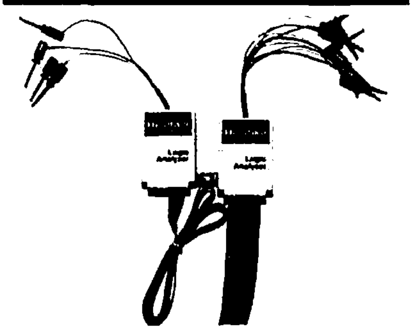
Internal view of the IC-1001 showing the printed circuit board layout. Note the clean design.

PHOTO C



Rear panel of the IC-1001 contains all of the connections to the environment.

PHOTO D



PODs are used for connecting the IC-1001 tc the circuit under test.

Although my hands are mildly arthritic and a bit plump, I found nothing hard about building the IC-1001. It's rare that I find no fault with the assembly of a kit, but I'm at a loss to find something negative to say about the IC-1001.

Using the IC-1001

The IC-1001 logic analyzer has a clean-cut front panel (see Photo A) with just an ON/OFF switch. The rear panel shown in Photo C contains all of the interconnections between the IC-1001 and its environment. The AC power connector on the left side is connected to the transformer wall plug that supplies power to the unit (the DC power supply is internal). The RS-232 serial port connector is the small DB-9 type that has become popular in recent years. (The 9-line "sort of" RS-232 has taken the place of the older 25-line RS-232 system.) A pair of trigger outputs is also provided. These BNC connectors output a signal, but one signal occurs at the trigger word while the other occurs after the specified delay.

There are three digital input ports on the read panel of the IC-1001. One is a clock input and the others are for the data word. The "high" byte accommodates the upper 8 bits of a 16-bit line, while the "low" byte accommodates the lower 8. These inputs link to the external circuitry being tested through a set of builder-assembled POD devices (see Photo D). These data line cables have a "hook plunger" clip on the ends to hook into the circuit being tested.

The Heathkit IC-1001 is a useful easy-to-build piece of digital test equipment. I've used mine for about six months and I'm a satisfied customer. For more information about the IC-1001 Logic Analyzer (priced at $279.95) contact The Heath Company, Benton Harbor, Michigan, 49022.

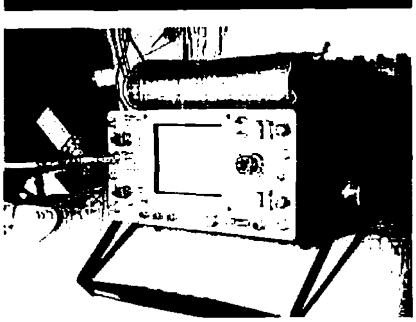
Other instruments

As is true in most areas of electronics practice, the oscilloscope (see Photo E) is the most useful instrument for many digital troubleshooting jobs. The oscilloscope will display one or more time-varying signals. You read amplitude along the vertical axis and time along the horizontal.

For digital work, select a model with a high frequency vertical bandwidth (20 MHz or better) and more than one channel. The most common form of 'scope may be the dualbeam (which really means two channel). For a bit more money you can get up to four channels. For lower frequency work, it's possible to convert a dual channel 'scope into a four-channel model using an external switching circuit.

Low capacitance probes are a must. In fact, they are a must for most types of testing or measurement. These probes do not capacitively load the circuit under test. This means they produce a better rendition of the waveform in the circuit. The standard 1:1 and 10:1 switchable probes offered by most oscilloscope manufacturers are low cap types.

PHOTO E



The oscilloscope is still the best friend of the servicer!

Oscilloscope probes are not just used for measurement. At a major university medical center on the East Coast, patients in the Intensive Care Unit (ICU) were monitored by a computer located in another building. Because this was in the early seventies and microcomputers and small minicomputers weren't yet invented, a relatively large computer was needed for the task. (ICUs today often run on IBM PCs.) The analog data was converted to a digitized format in the hospital ICU and transmitted across the street by a crude early form of modem.

At the computer room in the basement of the nearby building, the modem tones were demodulated to digital signals for input to the computer. Unfortunately, they were highly erratic and error warnings were common. The technician would try to find the problem, but it cleared up when he connected the low cap probe to the modem output. Thinking it was the cable plus the 'scope input capacitance, he tried shunting an equivalent value disk ceramic across the same point, but to no avail. Only the 'scope probe worked. That oscilloscope probe remained inside that computer rack for another 18 months when the experimental program was finished.

If you go to any well-equipped parts distributor or look in the catalogs of companies that sell test equipment, you'll find a series of logic probes for sale. These devices are handheld instruments that look a bit like fat oscilloscope probes, but don't connect to other instruments. There seem to be two or more distinct types. One probe, for instance, supplies either a logic level transition or a pulse when the button is pressed. These pulses (or levels) can be used to stimulate a digital circuit. A logic level can be generated by a circuit like the one in Figure 1A, while a brief pulse can be generated by the one in Figure 1B.

The other kind of logic probe is a pulse catcher. This device remains dormant until it receives a pulse. It then latches in one of its two stable states and produces an LED output indication. You can build a pulse catcher (of sorts) from a reset-set (R-S) flip-flop as shown in Figure 1C.

The circuits in Figures 1A, 1B and

ɔn't really replace a logic probe ɾor convenience, but they do make dandy little construction projects. If you want to construct an experimental digital breadboard, you can build in these circuits to make your work a little easier. These breadboards use a kind of IC strip socket with a lot of holes arranged in parallel rows and columns, laid out in the 0.3-inch × 0.1-inch standard DIP pattern. Number twenty-two hookup wire is pressed into the holes in the socket to make interconnections. These strip sockets are available from most parts distributors. Use as many IC strip sockets as you need to mount the chips. Provide +5 volts DC at 1 A, ±12 volts DC at 0.5-A DC power supplies, and a few pulse generators and catchers, and you'll be in business.

An oscillator that can be used as a clock or clock replacement in digital circuits is another useful piece of test equipment. If you want to make a digital oscillator, use a 555 IC timer connected in the astable mode (and connected to a +5 volt DC power supply). Or, if you have a square wave generator, you can make it into a suitable clock by providing a TTL output. On my Heath IG-18 (an oldie) I provided the output by using a CMOS 4050 chip (operated from +5 volts DC) as a TTL output buffer (**Figure 2**). The input of one stage of the 4050 is connected in parallel with the square wave output. The output level control must be set to something over 3 volts peak for the circuit to work properly. I added a separate BNC jack on the front panel for the TTL output so I wouldn't ruin the regular bipolar ±10 volt square wave output.

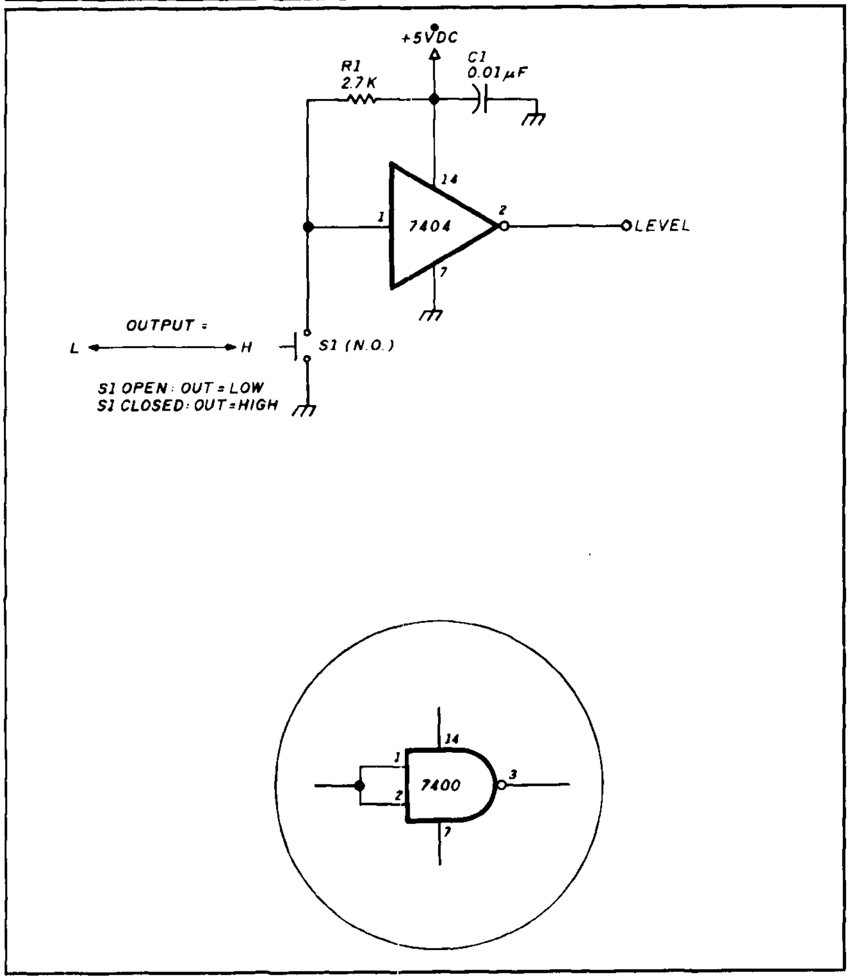
Now let's shift gears a little bit.

Why can't I ham it up in the hospital?

A reader collared me at the swapfest operated by the ham club at Goddard Space Flight Center in Greenbelt, Maryland. He had been hospitalized for surgery in the same hospital where I was once employed as a bioelectronics and biomedical engineer. He was perplexed and annoyed that the hospital authorities wouldn't let him keep his 2-meter, 5-watt handheld transceiver. He wanted to know why they were so narrow minded. Because I helped formulate some of the hospital rules involving radios about a decade ago, I was able to give a little insight.

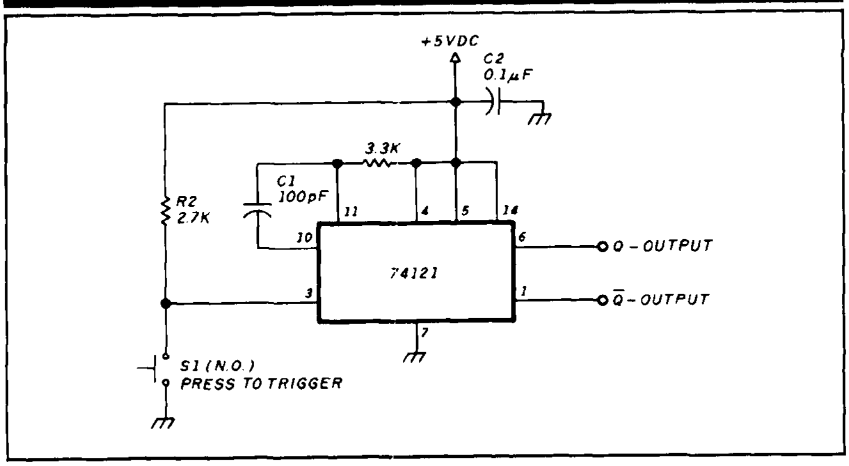
Modern hospitals are complex

FIGURE 1A



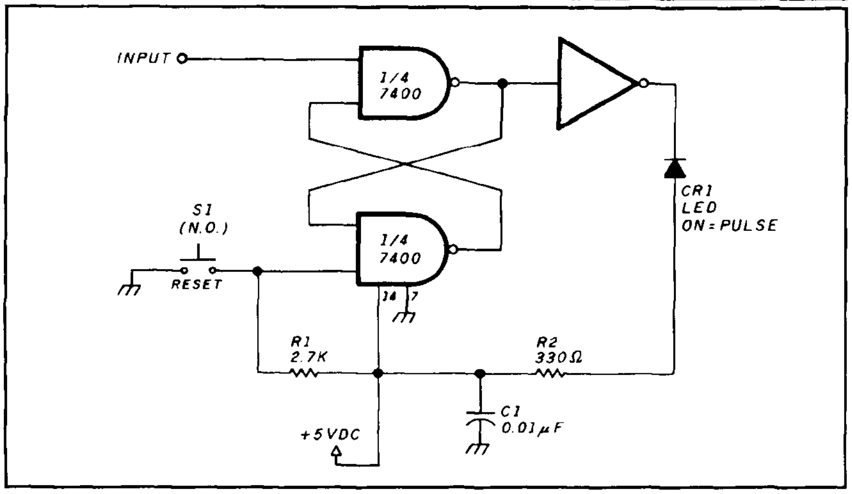
TTL level generator uses a 7404 TTL hex inverter (five sections of the 7404 are available for other uses). If an inverter is not available, then one can be made by shorting together the two inputs of a 7400 NAND gate.

FIGURE 1B



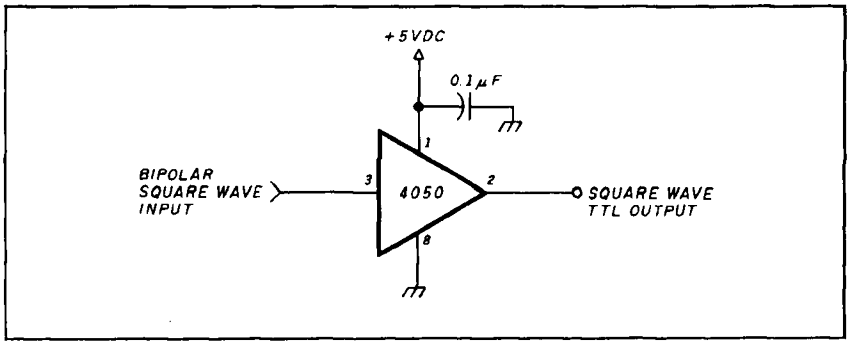
A 74121 TTL one-shot chip outputs both Q and NOT-Q 100-nS pulses when the pushbutton is pressed.

FIGURE 1C



Pulse catcher is an R-S flip-flop with an output indicator. Initially press S1 to reset the circuit. Thereafter, when a pulse is received it will turn on the LED.

FIGURE 2



A CMOS 4050 is used to convert bipolar squarewaves to TTL-compatible squarewaves.

places with a large array of electronic instruments for monitoring and treating patients. Some of these instruments are EMI sensitive. While a TVI complaint in your neighborhood isn't an earth-shattering event, a nonworking patient monitor in the coronary care unit or telemetry unit can cost someone his life.

Very early one morning in the mid-seventies I was trying to troubleshoot a problem. An electrocardiograph (ECG) VHF telemetry signal was riding in on the wrong channel, obscuring the signal of the patient to whom it was assigned. I traced the problem to EMI from the local oscillator of an FM broadcast receiver. The FM radio whip was only a foot or so from the 17-inch telemetry whip hanging from the ceiling, where it was connected to a 60-dB wideband VHF preamplifier. The problem was an old-fashioned intermod situation.

We banned FM radios at the nurses' station that night. While we could have gotten away (technically, that is) with banning the single offending station on the FM dial, it seemed more reasonable to just ban the radios altogether. During that same era, incidently, the airlines banned FM radios on flights. It seemed that the FM LO could also interfere with avionics gear.

While I sympathize with the sick ham (when I was "in" for a gall bladder operation in 1986 I had to live by my own rule), it seems that the rule is here to stay in most hospitals.

That's all for this month. I can be reached at POB 1099, Falls Church, Virginia 22041 and would like to have your comments and suggestions for this column. hr

A LOW-NOISE DESIGN PRIMER

Some ideas on improving receiver noise

By Bob Lombardi, WB4EHS, 1874 Palmer Drive, Melbourne, Florida 32935

Noise. Throughout the history of Amateur Radio, noise has been one of our biggest problems. Few topics have had quite so much written about them in the Amateur literature or in professional circles. Because of this coverage, newcomers to the field may feel overwhelmed by the references available. In what follows, I've attemped to cover the subject in enough depth to allow you to complete some designs and feel comfortable with the subject. There are a couple of types of noise that are the most frequent contributors to receiver noise problems; I'll start by treating them separately.

Thermal noise and the universe

The discovery that any component above absolute zero in temperature generates thermal noise proportional to its temperature is attributed to Ludwig Boltzmann, one of the great physicists of the nineteenth century. Boltzmann's relationship shows that the noise voltage generated depends on the temperature of the component, its resistance, and the bandwidth in Hz that you measure in, or:

$$E = (ktBR)^{1/2} \qquad \textbf{(1)}$$

where t is temperature in degrees Kelvin, B is bandwidth in Hz, R is resistance, and k is Boltzmann's constant (1.381 $\times$ 10^{-23} Joules/K degree).

In terms of power:

$$P = \frac{E^2}{R} = ktB \qquad \textbf{(2)}$$

A 50-ohm resistor measured at 20 degrees C in a 1-Hz bandwidth delivers a power level of 3.98 $\times$ 10^{-21} watt. It's customary in receiver work to refer to power levels with respect to 1 mW, and this power is −174 dBm. Of course no receiver could better that mark, but the 1-Hz bandwidth is almost never used in real life. Because power increases directly with bandwidth, the level goes up 10 dB for every times 10 increase in bandwidth. In a 2-kHz bandwidth, for example, the power level goes up by 33 dB, to −141 dBm. This is close to the case for a typical SSB signal.

This level is roughly 7.9 $\times$ 10^{-21} watt, or 0.020 μV in 50 ohms. A typical "good" HF receiver will claim 0.50 μV sensitivity, but although this may seem poor when compared with the thermal noise value, it's actually better than you need. The noise that we often refer to as QRN is the reason.

There are many sources of QRN: the sun, certain astronomical sources, the din of distant thunderstorms, and a myriad of urban and suburban noise sources. The noise level at the receiver input from these sources determines the receiver's useful sensitivity. **Table 1** shows typical numbers used in the design of HF radio links[1].

The numbers in this table are normalized for bandwidth; just add this number to the thermal noise floor described earlier to reach the usable sensitivity. For example, at 30 MHz in a typical suburban location you would add 38 dB to the SSB noise floor of −141 dBm to get −103 dBm. This translates into 1.58 μV in 50 ohms. Suddenly that 0.5 μV sensitivity seems generous. Furthermore, the noise at lower frequencies is even higher and storms create even more noise.

Noise from the receiver and noise figure (NF)

All electronic amplifiers currently available produce some noise along with their amplification. This noise takes several forms including shot, popcorn, and schottky noise. The exact nature of each type of noise is related to the physics of the devices used and is not really important here. For now it's enough to know that such noise exists and is unavoidable — at least to some degree.

Most hams have heard the term noise figure before, especially those who operate VHF/UHF in the weak signal modes. The definition of noise figure used by Friis in 1944[2]

TABLE 1

Typical numbers used in the design of HF radio links.

Frequency MHz	Quiet Rural	Quiet Suburban	Noisy Suburban	Noisy Urban
	Location			
10	40	42	48	62
20	22	30	40	55
30	17	28	38	51
50	13	20	31	46
144	0	0	9	22

is perhaps the simplest and the best. According to Fris, the noise figure of a network is the signal to noise ratio of the input divided by the signal to noise ratio of the output, expressed as a decibel ratio, or:

$$NF = 10 \, Log \frac{S/N \, in}{S/N \, out} \qquad \textbf{(3)}$$

This means the noise figure is the decrease or degradation of the signal to noise ratio as the signal goes through the network. Notice that this implies at least a two port network with one output and one input.

Because noise figure is a property of two port networks, it isn't the right term to use for the characterization of oscillators or terminations. Terminations have their noise level set entirely by Boltzmann's ktB. Oscillators will produce noise along with the desired signal, but this is best expressed as a carrier to noise ratio.

Mixers, on the other hand, are three port networks and do have a noise figure. The noise present on the local oscillator also comes into play here; LO noise adds directly to the noise already present on the desired signal, degrading the S/N ratio even more. The common double balanced mixer is a passive network, and so has its insertion loss as its noise figure.

LO C/N (carrier to noise) ratio is more of a concern today than it was before the advent of the PLL synthesizer. Synthesizers can be quite poor from the standpoint of noise sidebands — a problem that was almost unheard of in the era of crystal oscillators. I'm sure many of you have noticed that when the ham down the block gets a shiny new rig, the noise floor of the universe jumps up every time he transmits.

Finally, note that noise figure is independent of gain or modulation.

Cascades of amplifiers, each contributing gain and noise, result in a change of noise figure from that of the front end noise figure. The method of calculating cascade noise figure is simple, but it requires a little manipulation. The noise figure must be converted to its ratio by taking the antilog of NF/10 (I'll call this F) and the gains of the stages must also be expressed as ratios, not in dB. Given this:

$$F_{system} = F_1 + \frac{(F_2 - 1)}{G_1} + \frac{(F_3 - 1)}{G_1 G_2} + \ldots \frac{(F_n - 1)}{(G_1 G_2 \ldots G_{n-1})} \qquad \textbf{(4)}$$

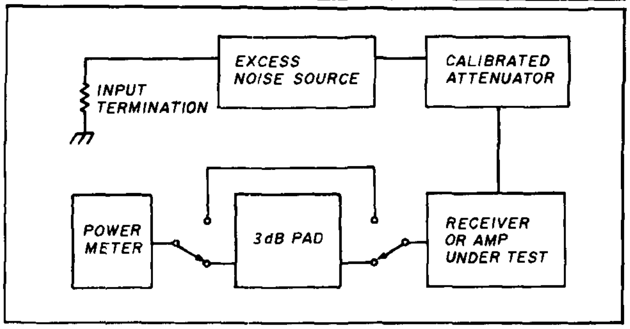
where the subscripts 1, 2, ..., n, denote the stage number proceeding from the front end, stage 1, back. It should be obvious that if the front end is high in gain and low in noise figure, it essentially sets the system noise figure. Furthermore, regardless of gain, you can never be better than the front end.

Measuring NF

While measurement of noise figure is done commercially with specialized (read that expensive) test equipment, it's possible to measure it with methods accessible to the Amateur.

The most straightforward method is the twice power or 3-dB method. You need a noise source with a known excess noise ratio to perform this test. Probably the biggest problem is knowing your excess noise ratio — the amount of noise that the source puts out over an equivalent resistor at the same temperature. Reverse biased zener diodes are frequently used to generate noise; they can provide 30-dB of excess noise ratio. Surplus vacuum tube noise sources

FIGURE 1



Test setup for measuring NF.

are available from time to time and are usually characterized, or can be.[3] In this method, shown in **Figure 1**, only three steps are required:

- Set a convenient power level reference at the power meter with the noise source "out" or "cold." The power meter can be measuring actual detected RF power on a microwattmeter or audio power at the receiver speaker terminals.
- Insert the 3-dB pad and turn on the source.
- Vary the attenuation until the reference is obtained.

At this point, the attenuated excess noise ratio of the source is the noise figure of the receiver. The noise figure is the excess noise ratio (ENR) minus the attenuator setting in dB.

Ideally, the calibrated attenuator would be a continuously variable type, but a step attenuator will do if you can find one with small enough steps. Lacking that, precut lengths of cable will make calibrated attenuators that are easy to coil up and keep around. You'll need different lengths for each band of interest, lots of connectors, and cable that you can trust to meet some attenuation versus frequency curves. If you don't have this type of cable, you'll need a way of measuring the attenuation directly (e.g., your microwattmeter).

Minimum Discernible Signal (MDS) and Noise Figure (NF)

Noise figure is an excellent figure of merit for receivers. Unfortunately, it doesn't tell the complete story. The minimum discernible signal (MDS) is another important number. MDS, just as its name imples, is the weakest signal that the receiver can detect at some level of readability. The low NF alone doesn't do much good if the receiver can't hear below a millivolt. You'll recognize this as another way of stating sensitivity, although the results are usually stated as dBm in 50 ohms. A poor MDS means that there is insufficient gain in the receiver, usually at the IF, because the front end will amplify anything that hits it.

Designing for Low NF

The selection of the front end device is the best place to start in a low noise design. It should come as no surprise that FETs are generally capable of better noise performance than bipolars. GaAsFETs, silicon MOSFETs, and JFETs are good choices for hams in the VHF and above spectrum, as they are readily available and reasonably priced. The newer HEMTs (High Electron Mobility Transistors) are really HEMFETs and may be the "new wave" in microwave design.

FIGURE 2

```
10  REM  Noise figure program that solves the Cascade NF equation
20  REM  demo driver for Ham Radio Magazine
30 REM Bob Lombardi  W4EHS  July 1989
40 PRINT"* * * * *  System Noise Figure and Gain Analysis  *  *  *  *"
50 PRINT
60 INPUT "Enter number of stages"; NUMBER
70 DIM STAGE (NUMBER, 3)
80 FOR I=1 TO NUMBER
90 INPUT "Enter stage NF (in dB), and gain (in dB)"; STAGE(I,1), STAGE(I,2)
100 STAGE(I,1)= 10^(STAGE(I,1)/10)
110 STAGE(I,2)= 10^(STAGE(I,2)/10)
120 STAGE(I,3)=1
130 NEXT I
140 FOR J= 2 TO NUMBER
150 STAGE(J,3)= STAGE(J-1,3)*STAGE(J-1,2)
160 NEXT J
170 FSYS = STAGE(1,1)
180 FOR I=2 TO NUMBER
190 FSYS = FSYS+ (STAGE(I,1)-1)/STAGE(I,3)
200 NEXT I
210 PRINT:PRINT:PRINT
220 PRINT "System NF is "; 10*LOG(FSYS)/LOG(10); " dB."
230 PRINT "system gain is"; 10*LOG( STAGE(NUMBER,2) * STAGE(NUMBER,3)) /LOG(10);
" dB."
```

Listing of BASIC program for solving cascade noise figures.

I'm not aware of these devices being available to hams. Bipolars have made recent progress in this area, and are often a reasonable choice.

Once you've chosen the front end, use **Equation 4** to optimize the rest of the receiver chain. I've included a simple BASIC program (**Figure 2**), based on **Equation 4**, to calculate the system gain and NF of a cascade of gains and losses. (The program is in GWBASIC for the IBM PC and clones, but you should be able to translate it to other machines with no trouble.) It's often helpful to add more gain at a more modest NF before the first mixer, especially if it's a double balanced one. Remember that passive circuits like pads or filters have conversion loss, so their through loss is used as their NF and negative gain in the equation.

The data sheets for the device you've chosen frequently provide some bias information and input impedance for minimum NF. These data have a habit of either being at the wrong frequency, or just plain incomplete. Many times a designer chooses a device simply because its data sheet is more complete than others and leaves less room for guesswork.

Biasing the device for the desired collector or drain current is relatively straightforward,[4] but should not be ignored. The bias must be stable for all variations expected in operating conditions, like the temperature extremes of a mast mounted preamp.

Matching to the device is done via manual methods, Smith Chart,[5] or computer (or both*). It's best to leave some adjustability in the design of the matching network to allow for part-to-part variations, and to use the highest Q (lowest loss) components that you can get.

An example of a simple circuit design is included in Appendix A to show these ideas in a more concrete form.

Designing for low noise is easier than correcting for it later. Consider the ideas and references presented here before trying your next receiver design.

REFERENCES

1. *Reference Data for Engineers: Radio, Electronics, Computer and Communications*, 7th Edition, Howard W. Sams Company, Inc., 1985, pages 34-39
2. H.T. Friis, "Noise Figure of Radio Receivers," *Proceedings of the IRE*, July 1944, pages 419-422.
3. G.P. Jessop, *VHF/UHF Manual*, Radio Society of Great Britain, 1983, pages 11-22
4. Chris Bowick, *RF Circuit Design*, Chapter 6, 1982, Howard W. Sams Company, Inc., pages 117-120.
5. Op. cit., Chapters 4 and 5.

*Various Amateur and commercial software packages are available to perform this function.

Appendix A
Design Example

Design a low noise amplifier to operate at 432 MHz with an NF of 1.5 dB or less.

The data sheets for the Avantek AT-41472 show that the device is capable of a typical NF of 1.3 dB when biased for a collector current of 10 mA. This will yield a stage gain of 14 dB (typical). Since the S parameters are supplied at 400 and 500 MHz, I'll interpolate a set of S parameters for 432 MHz linearly. (Knowing that the actual device will likely vary from these, I'll build in some adjustment.)
When Vce = 8 volts and Ic = 10 mA:

S11		S21		S12		S22	
mag.	ang.	mag.	ang.	mag.	ang.	mag.	ang.
0.32	−44	7.46	99	0.052	71	0.66	−20

Step 1: Bias the device:

Assumptions are Vce = 8 volts, Ic = 10 mA, Ve = 2.5 volts, hfe_{dc} = 30, Vcc=12 volts.

$$Re = \frac{Ve}{Ie} = \frac{2.5}{0.01} = 250 \text{ ohms (249 standard)} \quad \textbf{(1)}$$

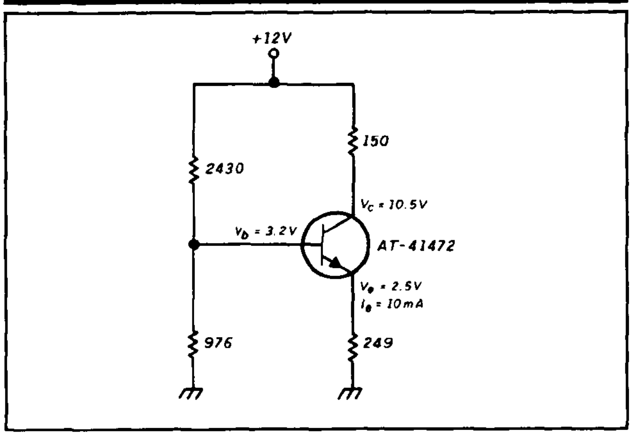
$$Vc = 2.5 + 8.0 = 10.5 \text{ volts}$$

$$Rc = \frac{12-10.5}{0.010} = 150 \text{ ohms} \quad \textbf{(2)}$$

$$Rbb = \frac{3.2 \text{ volts}}{3.33mA} = 960 \text{ ohms (976 standard)} \quad \textbf{(3)}$$

$$Rbt = \frac{12-3.2 \text{ volts}}{(3.33+0.33)} = 2404 \text{ ohms (2430 standard)} \quad \textbf{(4)}$$

FIGURE 3



DC biasing of the device.

The complete DC bias is shown in **Figure 3**.

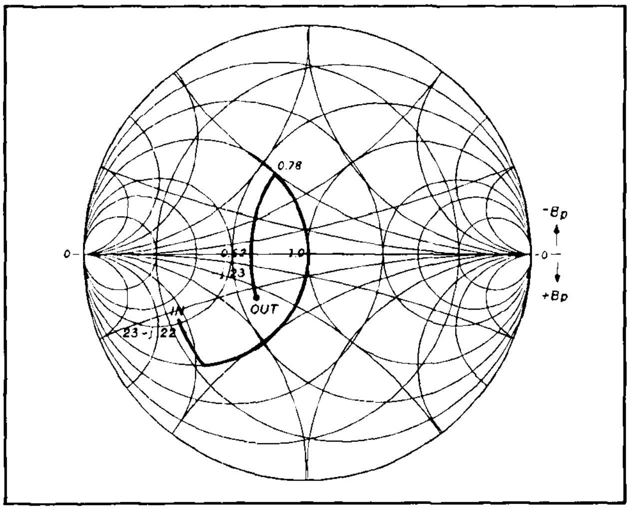
Step 2: Match the impedance of the input and output.

Although the data sheet for this transistor doesn't show an optimum source impedance for lowest NF, the data shows that the NF in a 50-ohm system is very close to the optimum NF. Consequently, I'll design for matching a 50-ohm source and load. **Figure 4** is the Smith chart used to find the matching networks.

Figure 5 is the final version of the amplifier. Note that both input and output were matched by simple L networks. The 470-pF caps are used as RF coupling/DC blocks and the emitter bypass. The cap at the emitter should be a chip cap, and should be mounted as close as possible to where the emitter leaves the case. The coils, though small, are buildable using small diameter air-wound inductors and minimal leads.

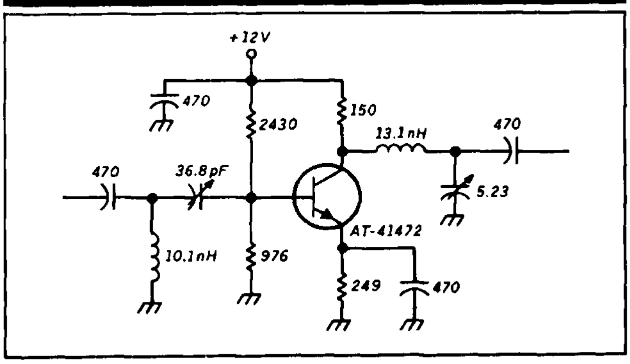
Although I didn't build this circuit, I did verify that it passes computer simulations. *My purpose here is not to present a working LNA design, but to demonstrate the design process.* According to a professional CAD program, the amplifier has a gain of 13.26 dB at 432 MHz. I couldn't analyze the noise figure due to limitations in the manufacturer's data, but the resultant gain and input impedance agree closely with the data sheet's prediction for gain at minimum NF. The procedure is essentially the same if the source impedance for optimum noise figure isn't 50 ohms, with the exception that you match to the different value.

FIGURE 4



Smith Chart plot of the complex matching impedance.

FIGURE 5



Complete circuit with matching networks.

(continued from page 6)

True believer

Dear HR

Congratulations on your editorial in the September 1989 issue of *Ham Radio*. You have presented a balanced, concise viewpoint which is also well written.

While I was not especially keen on your magazine, you are making a believer out of me! Recent issues have been very informative, and I now look forward each month to receiving my copy.

Keep up the good work.

Marvin J. Fein, Newport Beach, California

QSL cards available

Dear HR

The American Amateur Radio Club of Korea has in hand 55 pounds of QSL cards, some as much as 10 years old. These were recently released to KARL by the Postal Department. If you were (or know someone who was) a United States Forces Korea "HL9" during the past 10 years, a SASE to: American Amateur Radio Club of Korea, P.O. Box 153, APO San Francisco, California 96206, will get your cards. Don't forget to include your HL9 callsign and the dates it was valid.

Charles H. Kelley, W5SPK/HL9CK, PSC Box 5349, APO San Francisco, California 96366-0006.

Tom McMullen, W1SL

SIMPLE INSTRUMENTS — RF OUTPUT MONITOR

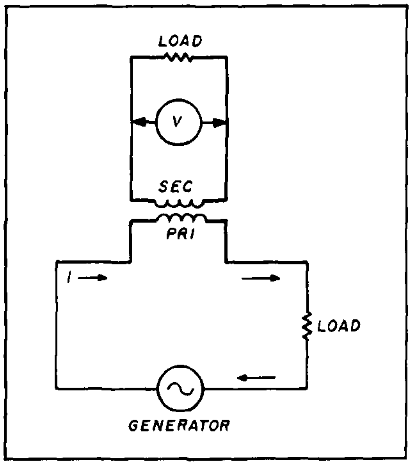
The RF output monitor can be used as a piece of test equipment for relative measurements, or as a station accessory that will constantly monitor the output of your transmitter. Construction is easy; it's basically a modified section of coaxial cable and an RF detector circuit. Similar circuits have been described in various publications before, but it's such a useful device that it's worth another look.

How it works

Before I get into the details of the device, let's take a look at the theory that makes it work. Everyone's familiar with the transformer shown in **Figure 1**. As with most transformers, it has a primary and a secondary winding. Current flowing through the primary induces current into the secondary, which can be applied to a load or measured with a meter. In many circuits, like household power lines and audio output circuits, the transformer is a part of the load, and whatever is hooked to the secondary winding is also part of that load. In **Figure 1** I've placed a load in series with the transformer primary. The transformer then responds to the amount of current that flows through the load by inducing more or less current into the secondary windings. If the load current changes, the voltage measured at the secondary will follow. By calibrating the meter carefully, you can determine the amount of power flowing through the load.

Notice that there's no iron core shown in the transformer in **Figure 1**. This should be a tip-off that the transformer is working somewhere in the radio frequency range, rather than at audio or power frequencies. From here it's an easy step to a device that will monitor the power being dissipated in an RF load (like an antenna).

FIGURE 1



In the familiar transformer representation, current flowing in a primary winding induces current into a secondary winding. The current in the secondary can be detected with a meter or applied to a load.

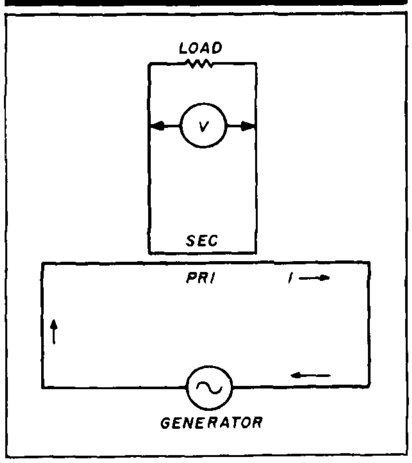
Figure 2 shows a similar RF transformer complete with primary and secondary "windings," although they don't necessarily look like windings. If we remember that even a straight piece of wire will produce a magnetic field when current flows through it (did you ever perform the good old experiment with a piece of bell wire, a lantern battery, and a compass?), then it makes sense that any current flowing in the center conductor of the coaxial cable will induce a current in the "secondary" wire that's very close by inside the metal shield braid (see **Figure 3**). That is really the essense of this simple test device. It's an RF transformer that produces a secondary current flow in response to the amount of current flowing in the primary circuit, which includes the load. This can be an antenna or dummy load, depending on which is hooked to the end of the coax. Now, let's build one.

Construction

As long as you're working at frequencies in the 3.5 to 50-MHz range, there's nothing really critical about the construction. Just follow good construction practices. For frequencies of 25 to 50 MHz, a piece of RG-8/U (or similar) cable approximately 4 to 6 inches long will suffice. You'll need a couple of connectors (your choice) to fit on the ends of the cable, as well as a diode and some other parts. If you can find them, I suggest using connectors that have a "funnel" type hood that connects to the shield braid — it makes a very neat job.

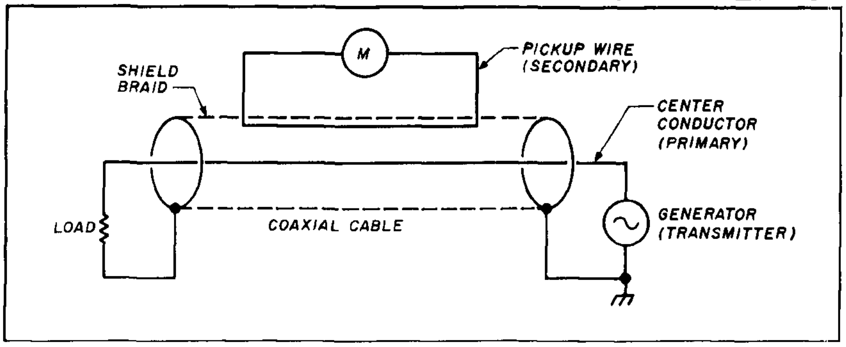
The idea is to assemble the section of coaxial cable with a fitting on each

FIGURE 2



A radio-frequency transformer can be simplified to a single-wire primary which induces a current in a single-wire secondary.

FIGURE 3



When the single-wire primary "winding" is the center conductor of coaxial cable, the secondary can be a single wire placed inside the braid to intercept the magnetic field surrounding the primary.

end and to place a small insulated wire inside the shield braid, bringing the ends out to a diode rectifier and a metering circuit (see Figure 4). You can connect the fitting on one end of the cable, including the braid. Leave the other end bare for the moment. Remove all the vinyl covering from the cable and "bunch up" the braid so the weave is open enough to feed the piece of insulated wire in under the braid through a couple of small holes in the weave. Keep the wire far enough from the ends of the braid that the final soldering operation won't melt the insulation. When the wire is in place, stretch the braid out again to cover the center conductor and dielectric insulation, and install the fitting on the other end. If you can't find the hoods, "tease" the braid into a couple of pigtails and solder them to lugs that fasten to the flanges with screws and nuts. It's a good idea to cover the braid with a layer or two of plastic electrical tape to hold everything in place.

You can ground one end of the small wire to the coaxial fitting or to a chassis if you're building this assembly into a enclosure of some kind. Connect the other end of the wire to the anode end of a diode — use a small stand-off insulator to hold things in place. The cathode end of the diode can go directly to a microammeter for low power uses, or through a resistor to monitor higher power levels. You can experiment to find values that work with whatever transmitter power output you need. Several resistors and a switch, as used in the meter described in last month's column, will make the unit more versatile.

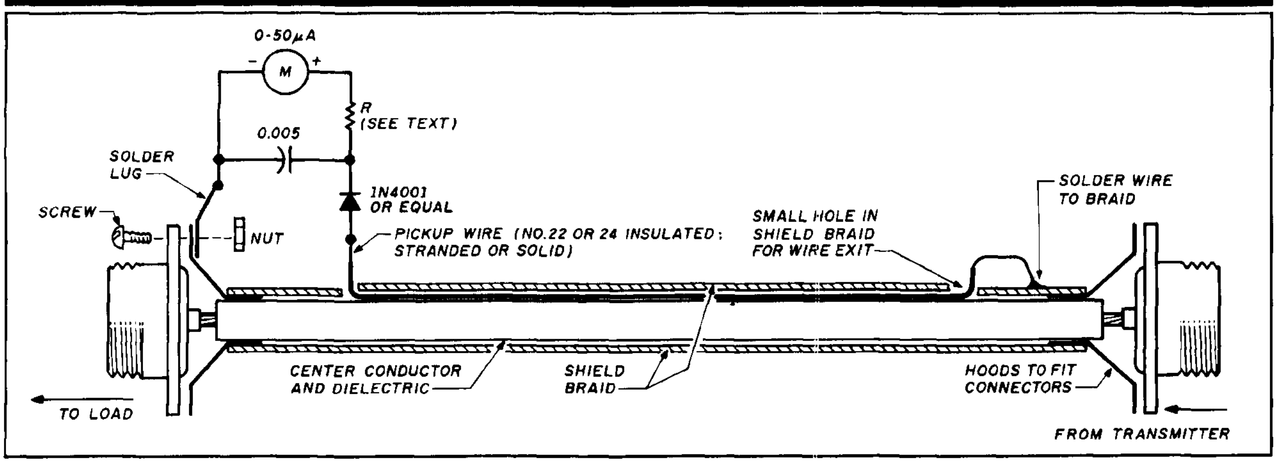
If you'd like something a bit more high tech than a common meter, you might try one of those integrated circuits that drive a bunch of LEDs in a "light-bar" arrangement. You'll find them at many electronic supply stores and in catalogs — including Radio Shack and Jameco. Just follow the instructions that come with the IC and LED assembly, and you'll have a power monitor that shows relative power output whenever you key your transmitter. The LEDs will even follow your voice when you use SSB.

Simple instrument, simple tasks

One thing to remember about this device is that it's not a true power output monitor. It shows *relative* output only. You could, if you're a dedicated experimenter and really fussy, use an accurate wattmeter and a good dummy load and work up a calibration chart for the meter. The catch is that it would be good for only that frequency and into a dummy load. When you change bands the meter reading will change, and any mismatch at the antenna will also change the reading to some degree.

This device is not intended to accurately indicate reflected power (or SWR). It will show some indication if you turn it around and take the end connected to the transmitter and connect it to the antenna feed line instead,

FIGURE 4



Construction of the *monitor* section. The pick-up wire (secondary winding) is threaded under the shield braid through small holes at each end. A layer of electrician's tape or heat-shrink tubing over the completed assembly will hold everything in place. The resistor value can be from 100 to 47 k or more, as required for the power level you use. The capacitor bypasses RF to keep it out of the meter circuit; a 0.005 μF disk ceramic rated at 50 volts or more will do.

but this reading may or may not mean anything. The reason is that the capacitance between the pick-up wire and the center conductor will always couple some RF energy into the secondary wire. True VSWR indicators are constructed to minimize or eliminate pickup because of this capacitance. The device will, however, be a very useful indicator of how things are working at either end of the feedline. If something drastic happens to either the antenna or the transmitter, you'll see a change in indication — and that's what this gadget was designed to show.

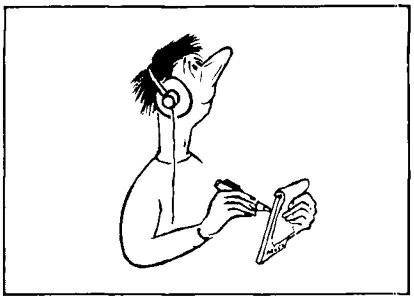
Other frequencies

I've had reasonably good results with this type of device at 144 MHz by using a 4-inch length of coax between fittings, and type "N" connectors rather than the usual SO-239/PL-259 types. At frequencies higher than this, the pick-up wire becomes a significant portion of a wavelength, and the extra wire in that short length of coax puts an "impedance bump" in the line. Amateur publications have described similar devices that use strip conductors made from pc board material. These work well at VHF and UHF. You can obtain improved readings at the lower ranges (3.5, 7, 10, and 14 MHz) by using a coax length of 6 to 8 inches between connectors.

If you want to build the RF transformer section into a metal box along with a meter or the LED indicators, it won't hurt to bend the coaxial section into a "U" shape so the connectors are accessible on either the front or back of the enclosure.

I've seen this type of device built with the secondary wire placed in a small groove cut into the coax cable dielectric. This increases the sensitivity slightly, but the tradeoff is that the secondary wire disturbs the impedance of the cable to a larger degree than does the simpler type of construction. If you're working at very low power ranges, it may be worth a try.

DX Forecaster



Garth Stonehocker, K0RYW

WINTER DX SEASON

November through February is the winter DX season for most of us. Signal strengths are roughly 15-dB stronger on paths to Europe from the United States due to lower absorption of signal energy by ions in the D region. In this season the Northern Hemisphere D and E regions receive less energy (thus less ionization) because the sun is in the Southern Hemisphere. On any propagation path, absorption increases with the number of signal transits of the D region and varies inversely with frequency. In working DX to use the higher frequency bands to obtain more distance per hop, which results in fewer transits and less signal loss. But don't make a habit of counting on this; signals traveling a high-latitude path may be poor for several days at a time. This is known as the winter anomaly.

Along with lower signal attenuation, QRN decreases as fewer local thunderstorms pass through your QTH during the winter months. The sun's southerly location also affects the distant land mass thunderstorm generators. As the large thunderstorms near the equator move farther south, their noise decreases by about 6 to 8 dB. This is particularly noticeable on the 160, 80, and 40-meter bands.

How do these two winter DX season signal propagation parameters affect your receiver input? The weakest receiver input that can be amplified and detected is a function of the input signal to noise ratio, S/N. For receivers used in the HF bands the ratio limitation is usually the atmospheric noise received at the antenna input. The preceding paragraph indicates that there's a decrease of noise in this season. Thus your receiver input S/N denominator, N, should decrease by about 6 to 8 dB. As was mentioned earlier, the signal attenuation from less absorption should increase the signal by about 15 dB during the winter months. Your receiver input S/N numerator, S, should see this. Therefore, a total increase of 20 to 23 dB is available for digging out the weaker DX — making this time of the year better than any other. Do you have an unfulfilled WAC goal, or a friend you'd like to talk to in a third world country where they use low power transmitters? Now is the season; go for it!

Last-minute forecast

Expect DX conditions on the higher frequency bands to be best the first, second, and last weeks of November. Solar flux with accompanying MUFs should be high at these times. Look for good transequatorial openings in late evenings too. These openings may be enhanced around the 7th, 17th, and 27th because of the possibility of disturbances then. November is often quiet geomagnetically, but anything can happen at sunspot maximum. The lower bands, mainly nighttime, are expected to perform best during the third and fourth weeks — including Thanksgiving weekend. It's time to sit by the fireside, away from the cold dark night, and DX a little.

The Taurids meteor showers will occur from October 26th to November 22nd, with a maximum count of ten per hour from the 3rd through the 10th of November. Lunar perigee is on the 12th and a full moon falls on the 13th.

Band-by-band summary

Ten and 12 meters, the highest day-only DX bands, are nearest the MUF for Southern Hemisphere paths. They will be open most days during the 8 to 12 hour period after local noon for the solar flux available this November. These bands open on paths toward the east and close toward the west. The paths are up to 4000 km (2400 miles) in single-hop length and, on occasion, double that during evening transequatorial openings.

Fifteen and 17 meters, day-only DX bands open most of each day, have lower signal strengths and greater multipath variability than 10 and 12 meters. This variability will be best when the MUF is resting just above these bands until it drops below (a transition period that occurs after sunrise and just before sunset). Transequatorial openings will occur with distances similar to 10 and 12 meters.

Twenty, 30, and 40 meters are both daytime and nighttime DX bands. Twenty is the maximum usable band for DX in northerly directions during the day. It provides nighttime paths for the day-only bands, in combination with 30 meters. Forty meters becomes the main over-the-pole DX daytime band, with some hours covered by 30 meters. This path and east-west paths may be affected by 1 to 20 dB of anomalous absorption during a few days of the month.

Eighty and 160 meters, the night-only DX bands, exhibit short skip propagation during daylight hours, then lengthen at dusk. These bands follow the darkness path, opening to the east just before local sunset, swinging more to the north-south near midnight, and ending up in the Pacific areas for a few hours before dawn. Remember the DX window of 3790 to 3800.

OVEMBER

WESTERN USA

GMT	PST	N ASIA FAR EAST	NE EUROPE	E S. AFRICA	SE S. AMERICA	S ANTARCTICA	SW NEW ZEALAND	W OCEANIA AUSTRALIA	NW JAPAN
0000	4:00	17	30	12	10	10	10	10	12
0100	5:00	15	30	15	10	10	10	10	15
0200	6:00	17	30	15	12	10	10	10	15
0300	7:00	20	30	17	15	10	10	10	17
0400	8:00	30	*30*	17	15	12	12	15	20
0500	9:00	30	*30*	17	15	12	15	15	20
0600	10:00	30	*30*	17	17	15	15	15	30
0700	11:00	30	*30*	*17*	17	15	15	17	30
0800	12:00	30	30	*17*	*17*	15	17	17	30
0900	1:00	30	30	*20*	*17*	*17*	17	17	30
1000	2:00	30	*30*	*20*	*17*	*17*	*17*	*17*	30
1100	3:00	*30*	*30*	*20*	*17*	*20*	*17*	*17*	30
1200	4:00	*30*	*30*	*17*	*20*	*17*	*17*	*17*	*30*
1300	5:00	*30*	20	10	10	*17*	*17*	*17*	*30*
1400	6:00	*30*	15	10	10	15	*20*	*20*	*30*
1500	7:00	30	15	10	10	10	17	15	*30*
1600	8:00	30	15	10	10	10	15	15	*30*
1700	9:00	30	17	10	10	10	12	20	*30*
1800	10:00	30	17	10	10	10	10	15	*30*
1900	11:00	30	20	10	10	10	10	12	30*
2000	12:00	*30*	30	10	10	10	10	10	15
2100	1:00	*30*	30	10	10	10	10	10	15
2200	2:00	*30*	30	10	10	10	10	10	12
2300	3:00	*30*	30	12	10	10	10	10	12

MID USA

GMT	MST	N ASIA FAR EAST	NE EUROPE	E S. AFRICA	SE S. AMERICA	S ANTARCTICA	SW NEW ZEALAND	W OCEANIA AUSTRALIA	NW JAPAN	CST
0000	5:00	30	30	15	10	10	10	10	12	6:00
0100	6:00	30	30	15	12	10	10	10	15	7:00
0200	7:00	*30*	30	15	15	10	12	10	17	8:00
0300	8:00	*30*	30	17	15	12	12	12	20	9:00
0400	9:00	*30*	*30*	17	15	12	12	15	20	10:00
0500	10:00	*30*	*30*	17	17	15	15	15	30	11:00
0600	11:00	17	*30*	*17*	17	15	15	15	30	12:00
0700	12:00	15	*30*	*17*	*17*	15	17	17	30	1:00
0800	1:00	17	30	*20*	*17*	*17*	17	17	30	2:00
0900	2:00	20	*30*	*20*	*17*	*17*	*17*	*17*	30	3:00
1000	3:00	30	*30*	*20*	*17*	*20*	*17*	*17*	*30*	4:00
1100	4:00	30	*30*	*17*	*20*	*17*	*17*	*17*	*30*	5:00
1200	5:00	30	20	10	15	*17*	*17*	*17*	*30*	6:00
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1600	9:00	30	17	10	10	10	15	15	*30*	10:00
1700	10:00	*30*	20	10	10	10	12	15	*30*	11:00
1800	11:00	*30*	30	10	10	10	10	12	20	12:00
1900	12:00	*30*	30	10	10	10	10	12	20	1:00
2000	1:00	*30*	30	10	10	10	10	10	17	2:00
2100	2:00	30	30	10	10	10	10	10	15	3:00
2200	3:00	30	30	12	10	10	10	10	15	4:00
2300	4:00	30	30	15	10	10	10	10	12	5:00

EASTERN USA

GMT	EST	N ASIA FAR EAST	NE EUROPE	E S. AFRICA	SE CARIBBEAN S. AMERICA	S ANTARCTICA	SW NEW ZEALAND	W OCEANIA AUSTRALIA	NW JAPAN
0000	7:00	*30*	30	17	12	10	10	10	20
0100	8:00	30	30	17	12	12	15	15	20
0200	9:00	30	30	17	15	12	15	15	30
0300	10:00	30	*30*	17	15	15	17	17	30
0400	11:00	30	*30*	17	15	15	17	17	30
0500	12:00	30	*30*	*17*	17	15	17	17	30
0600	1:00	30	*30*	*17*	*17*	17	17	17	30
0700	2:00	*30*	*30*	*20*	*17*	*17*	*17*	*17*	*30*
0800	3:00	*30*	*30*	*20*	*17*	*17*	*17*	*17*	*30*
0900	4:00	*30*	*30*	*17*	*17*	*17*	*20*	*20*	*30*
1000	5:00	*30*	17	10	*17*	*17*	*20*	*20*	*30*
1100	6:00	17	15	10	12	*20*	*20*	*20*	*30*
1200	7:00	17	15	10	10	15	15	17	30
1300	8:00	20	15	10	10	12	15	12	30
1400	9:00	30	15	10	10	10	15	12	30
1500	10:00	30	15	10	10	10	17	15	30
1600	11:00	30	15	10	10	10	15	15	*30*
1700	12:00	30	15	10	10	10	12	17	*30*
1800	1:00	30	17	10	10	10	10	15	*30*
1900	2:00	30	20	10	10	10	10	12	*30*
2000	3:00	30	30	10	10	10	10	10	17
2100	4:00	*30*	30	10	10	10	10	10	15
2200	5:00	*30*	30	15	10	10	10	10	15
2300	6:00	*30*	30	15	10	10	10	10	17

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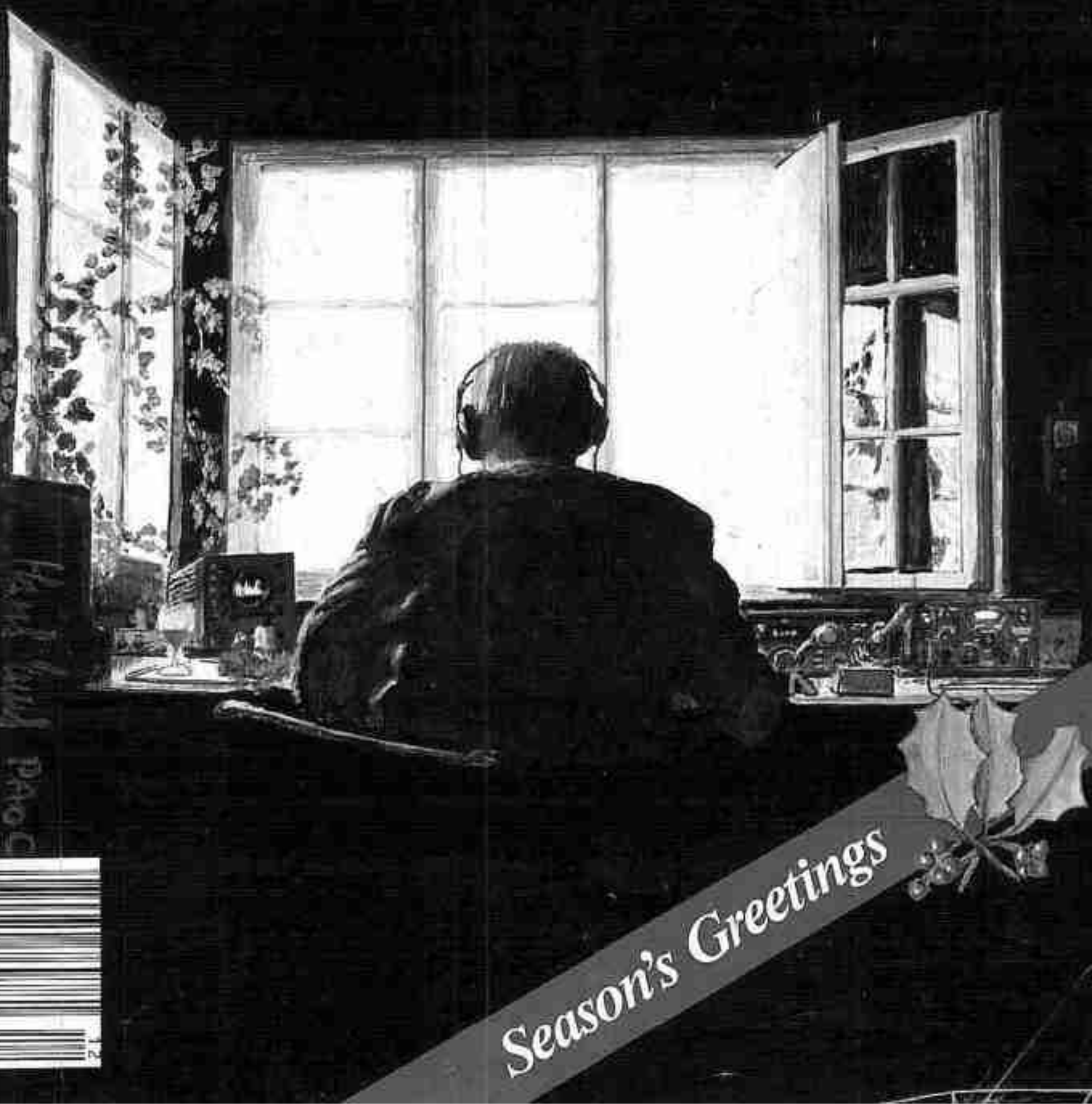
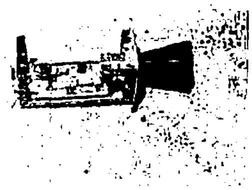
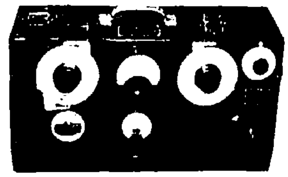


HAM RADIO



N6GN, page 9



W3QOM, page 49

DECEMBER 1989
Volume 22, Number 12

Cover Illustration: Hans Evers, PAØCX

FEATURES

DEPARTMENTS

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One of *Ham Radio's* Unsung Heroes

Most readers think of the staff at *Ham Radio* as editors, publishers, or staff members they may have met at Dayton or some other show. But it takes many more important people to complete the team that puts the magazine in your hands each month.

One of our "unsung heroes" is planning to retire at the end of this month, after 17 years in our circulation department giving outstanding assistance to both the magazine and its readers. Therese Bourgault is second in length of service only to myself.

Sue Shorrock, our circulation manager, has written a piece that not only pays tribute to "T", but also demonstrates the dedication that all of us at *Ham Radio* try to exhibit in bringing you the finest magazine that we can.

W1NLB

It seems like only yesterday that I started working with Therese Bourgault in the circulation department. Except that yesterday was in 1977.

My first day, 12 years ago, was memorable. After introductions all around I remember thinking, "They aren't really going to leave me alone in the same room with this female storm trooper, are they?"

But they did. Everyone else went back to work, and we were on our own. Because self-preservation is at the core of most human beings, I became an attentive student and a quick learner.

The first lesson was that there is only one way of doing things — T's way. I also learned that her way was the right way. Some more rules: As our subscriber you are number one. You are all to be treated equally and fairly. Your orders are to be processed quickly and carefully. If there is a problem we find out what happened, why it happened, and then correct the matter to your satisfaction.

Regardless of how busy or how frustrating things were, she always continued to do her work tirelessly. With time, humor, and our combined efforts to keep *Ham Radio* the best Amateur Radio magazine around, we became a good team and friends to boot.

Therese has devoted nearly 17 years of her career to making sure that you get the best possible service. During these years there have been some significant changes. One thing that never changed was her dedication to do the job and do it well. She has always been on your side.

I'm really going to miss working with T; she's been a good friend. But then, she always said if we're ever in a pinch....

Sue Shorrock

Comments

Author update

Dear HR

This letter is to clarify some points in my article, "A Simple DC Amplifier for Your Meter," *Ham Radio*, June 1989, page 10.

Figure 3 carries the note "Ground all unused pins of U1." The intent is to prevent feedback due to stray coupling with unused op amp units. In a letter I received from Robert A. Pease of the National Semiconductor Corporation, he agrees with grounding the unused input terminals, but recommends leaving the unused output terminals (numbers 7, 8 and 14) unconnected to save needless battery drain. I find that by disconnecting these terminals I save about 10 mA per terminal.

The type of pilot light used in **Figures 3** and 4 was not identified. I used light emitting diodes, and the series resistors RL are needed to limit the currents. Both should be 2.2 k. Resistor RL is shown incorrectly shorted out in **Figure** 4.

Yardley Beers, W0JF, Boulder, Colorado

Fair share

Dear HR

I'm writing in regards to your editorial "Amateur Radio Licensing Fees — The 'Non-Tax' Tax," (October 1989). I think you are too pessimistic in one respect, but not pessimistic enough in another.

You are right — any "user fees" collected by the FCC have to, by law, go into the General Fund and do not accrue to the FCC itself. But any statute passed by Congress can be amended by Congress. In seeking such an amendment, ham radio operators would have important allies. The National Park Service, for example, would very much like to have user fees collected at park entrances to be used to support and maintain the parks.

On the other hand, even if user fees collected by the FCC from Amateur Radio operators went directly into the FCC's budget, there is no assurance that the fees would be used for the benefit of Amateur Radio. The Commission has many other responsibilities and many other ways to spend money.

I think you are right in saying that "Amateur Radio will derive little or no benefit if the monies simply go into the General Fund." But you're wrong in thinking that Amateur Radio would necessarily derive any benefit if the fees were paid to the FCC directly.

Hugh Aitken, W1PN, Amherst, Massachusetts

A "Taxing" decision

Dear HR

Your "Backscatter" in the October issue will probably cause severe "Reflections" — and it should!

I was deeply upset after learning of the House Energy and Commerce Committee vote to levy fees for Amateur Radio licenses and several commercial ventures.

This is to reduce the federal deficit?

It's amazing that the esteemed committee would resort to "taxing" a group of voluntary hobbyists that have been, ever since the beginnings of Amateur (experimental) Radio, a national resource of self-trained and skilled individuals.

We have always been available, providing a public service without any compensation, in times of emergency — whether it be local, national, or international. In addition, we provide our government with a source of trained individuals, should the need arise, for the defense of our country. This has been proven a few times in this century.

The lack of growth (and even a decline) in Amateur numbers that occurred in the sixties was not due to the fees imposed at that time, but because of a general *deterioration of values* that swayed a generation of youth.

One has only to look back to a time when our country was in, and recovering from, an economic depression to see that the Amateur population was growing — although slowly at first. In those days of hardships, with more problems for our government than one could comprehend, an effective Commission was affordable and functioning well for its task — without Amateur Radio fees.

I can well understand the justification for fees on commercial interests in view of the fact that the profits obtained offset the costs.

In closing, I must express my disappointment in your willingness to accept this "tax" as stated in the article — even with your proposals.

Alex Hellman, W2OEQ, Woodhaven, New York

Where's the missing band?

Dear HR

Just received my October *Ham Radio* and read with interest the review of the Kenwood TS-950S. I feel that they would do better if they included the 20-meter band (Oops!) in the engineering specs on page 29.

Thanks for the article in any case!

Robert A. Du Brul, WB0RJR, Everton, Missouri

Whoops, our error! The 20-meter band is 14.0 to 14.35 MHz. Ed.

Do you have something you'd like to say? Address your comments to Dear HR, Ham Radio Magazine, Main Street, Greenville, NH 03055. Ed.

INEXPENSIVE MULTI-MEGABAUD MICROWAVE DATA LINK

By Glenn Elmore, N6GN, 550 Willowside Road, Santa Rosa, California 95401 and Kevin Rowett, N6RCE, 1134 Steeplechase Lane, Cupertino, California 95014

We'd like to tell you about some inexpensive antenna, radio, and computer interface hardware which allows communication of digital data at rates up to 2 megabaud (1 megabaud = 1 million bits per second) on an Amateur Radio band. In addition to the data link, an analog voice channel is provided. It requires only an external microphone and speaker for simultaneous full duplex audio communication. The link operates in the 10-GHz Amateur band and uses an inexpensive commercial parabolic antenna along with a Doppler radar transceiver module to provide medium range communications at low cost. We'll discuss modifications to surplus networking interface cards that let you use this high speed data in Amateur Radio service with IBM-style personal computers.

The Amateur accustomed to conventional AX.25 packet operation might wonder why anyone would want to go to the trouble of building a digital radio approximately 1000 times as fast as the 1200-baud systems prevalent on the VHF bands. Although many metropolitan areas are experiencing severe congestion on some of the packet channels, it's also true that many keyboard-to-keyboard QSOs are taking place. A great deal of traffic is also being handled on the worldwide bulletin board systems using today's equipment. The success of AX.25 packet radio has suggested the need for faster systems to improve current performance and has spawned some fundamentally new ideas for Amateur Radio.

A whole spectrum of new user applications and the possibility of a nationwide or even worldwide digital Amateur network are two major areas made possible by faster hardware.

New applications

Packet has been regarded as a way for two stations' computers to communicate, allowing keyboard-to-keyboard QSOs, but the potential for far greater applications exists Almost any information which can be transmitted by analog means can also be transmitted digitally, making digital audio, facsimile, graphics, and even digital TV feasible on the Amateur bands once sufficient data speed is available. The concept of repeaters for a variety of modes is conceivable, when combined with the ability of each Amateur station to serve as a relay of data to and from other stations. Amateurs will also be able to share resources. A station with an interesting database will be able to make it available to others. On-line call directories, QSL information, and technical data — not to mention computer programs and even the computers themselves — can be shared. It's possible for one Amateur to actually run programs and applications on someone else's computer as though it were located in his own shack. Remote control of equipment and remote sensing are other possibilities. Remote digital control of repeaters or even complete stations, including audio or video uplinks and downlinks, can be supported. Conventional voice repeaters (analog) may be replaced by digital hardware for completely digital round tables. Since this data can be transmitted anywhere the network permits, there can be multistate, national, or even worldwide voice nets. If the data rate permits, all of these different applications could conceivably be going on at the same time!

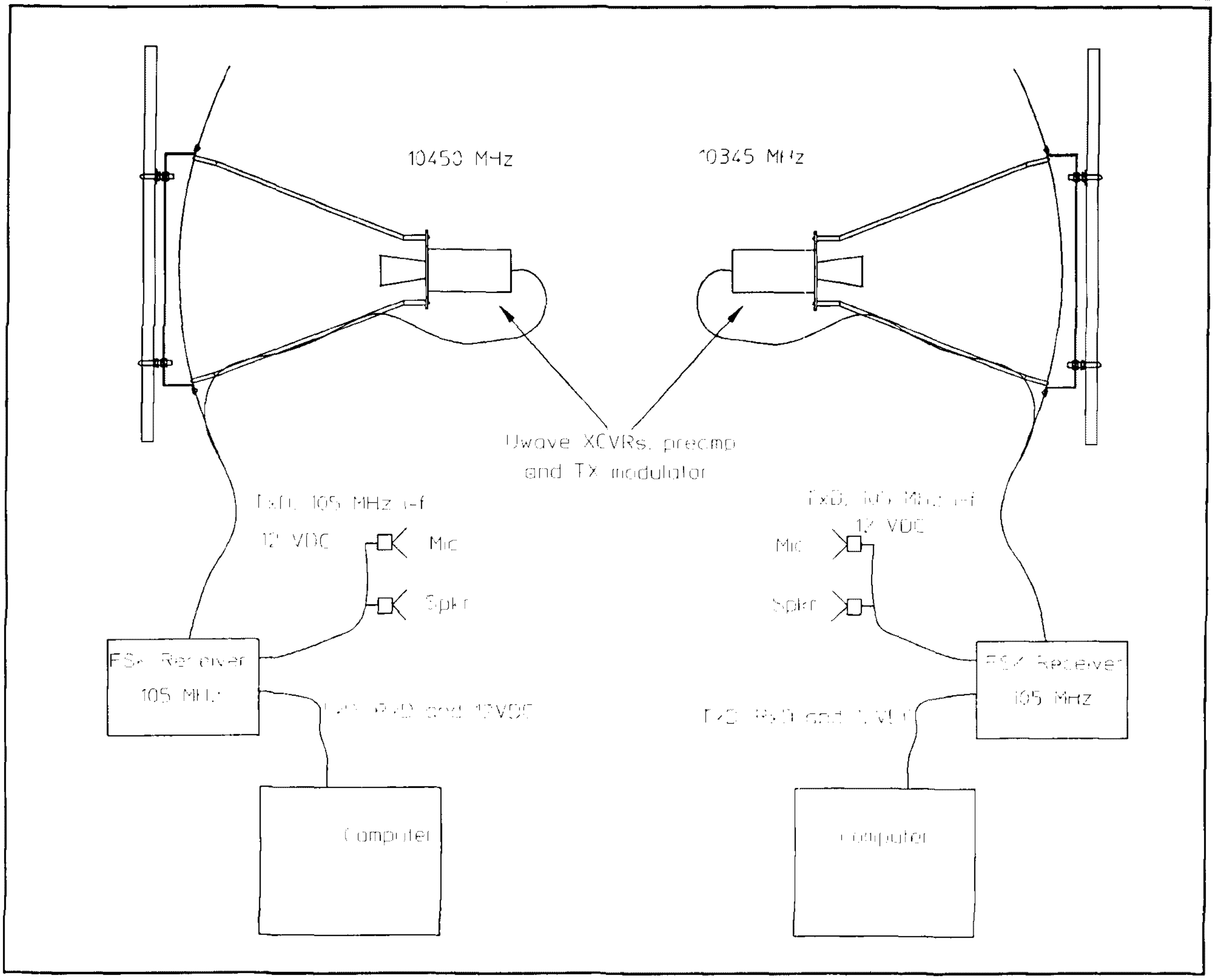
An Amateur Radio network

The possibility of an Amateur network is just as exciting as the variety of applications that high data rates can support. To date, groups of Amateurs have used limited networks for traffic handling and sharing information among members. A high speed digital network can provide these same services, as well as new applications, over very broad geographical areas on a full-time basis. A nationwide network capable of transmitting data quickly and with little delay could be beneficial to Amateur Radio public service and emergency operations. Data and resource sharing on a nationwide or worldwide network offers great potential in ushering the information age into Amateur Radio. The diversity of Amateur interests — DX, ragchewing, technical, and public service — could all be greatly enhanced by such a network. A network might also entice a great many potential and computer literate candidates into getting their tickets.

Goals

The link we'll describe was designed to help further the applications and networking made possible by high speed data exchange. It was built as an initial step in providing a moderate speed digital Amateur network in northern California to be used with a fledgling TCP/IP radio network.

FIGURE 1



System block diagram of the microwave high speed data link.

This was necessary to support some of the applications previously described. It was also built to help advance Amateur use of the microwave spectrum.

Fortunately, microwaves and high speed commmunication fit together very well. In fact, if the data rate is increased significantly it is absolutely necessary that wider and wider bands be used. As frequency is increased, antennas of reasonable physical size are better able to focus the transmitted beam without wasting signal in different directions. The Amateur microwave bands, through 24 GHz, offer the best available performance and cost for such communication. In order to be widely useful our link needed several attributes:

- To be inexpensive — competitive with present TNC/radio combinations
- Moderate speed — significantly faster than current alternatives of 1200 to 56,000 baud
- Medium range — at least 20 miles to be effective
- To use readily available parts
- To be simple to build and maintain
- To be reliable — a variety of applications may depend upon it

Problems

In addition to the problem of building radio hardware which the average Amateur could feel comfortable installing and maintaining, there are problems with the digital interface hardware portion of such a link.

At these speeds the data is too fast for normal serial ports on most computers, for the internal bus operations of many computers, and for TNCs. Similarly, the software to process data at these speeds can no longer operate on a character-by-character basis. Any solution we developed for these problems also needed to work with commonly available hardware, most notably the IBM PC and its clones.

Microwave hardware, propagation, and high speed data are new ground for many Amateurs. This means that any high speed link hardware needs to be relatively easy to work with.

What we built

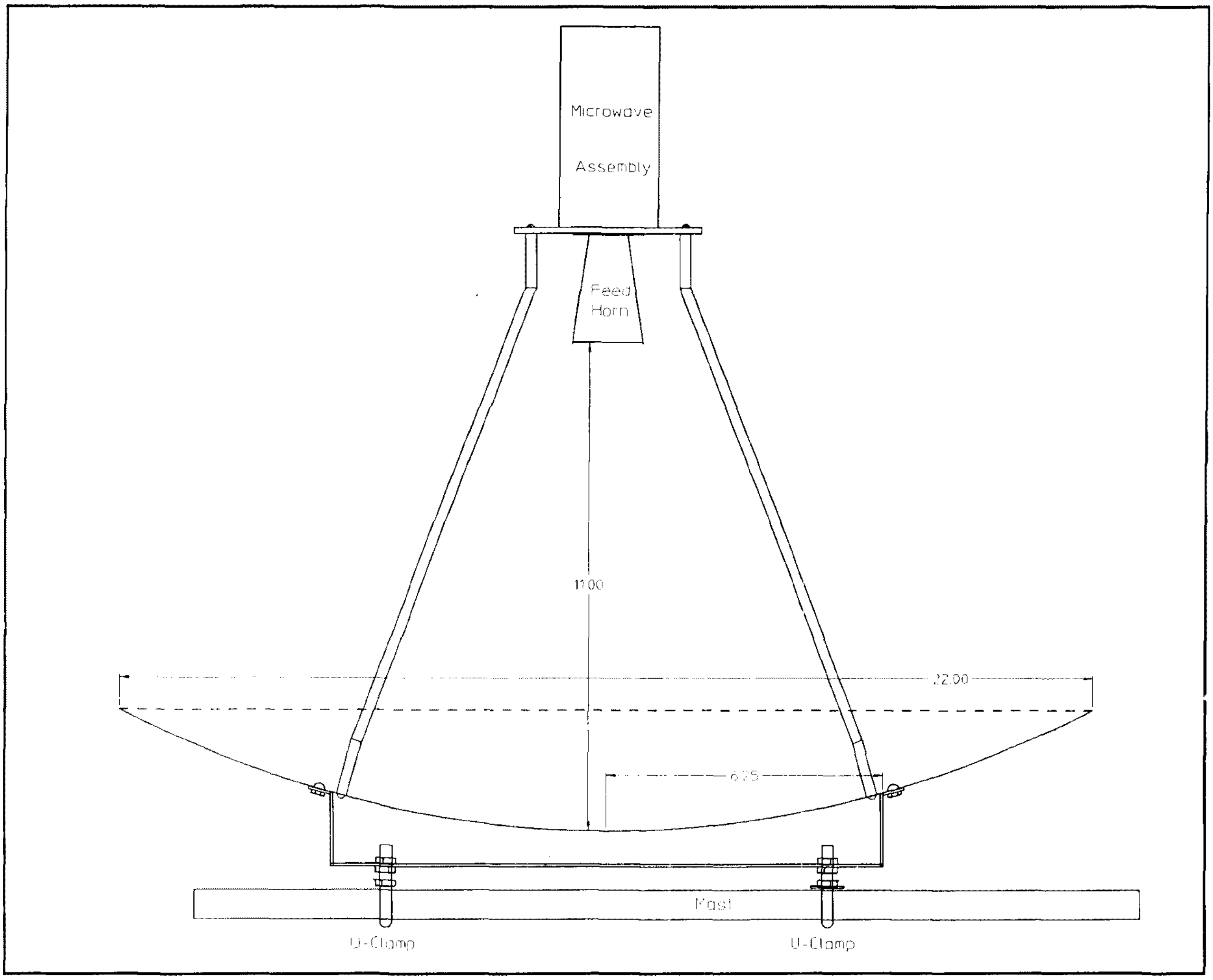
Previous successes using 10-GHz Gunn diode oscillators as local oscillators and transceivers for narrowband weak signal work, brought to mind the possibility of using these

inexpensive units for higher speed digital data transmission. In addition to being inexpensive, these units — which are commonly used for motion detection (door openers and burglar alarms), speed measurement (police radar guns), and microwave receivers (radar detectors) — have all of the microwave circuitry self-contained. This is important because it makes the equipment more attractive to non-microwave users. The system block diagram in **Figure 1** shows the operating principles.

The two ends of a link operate "split." One transceiver oscillator typically operates on 10,450 MHz while the other end is 105 MHz lower, on 10,345 MHz. The difference between the two transmitter frequencies corresponds to the receiver first IF frequency. The receiver first IF on each end is generated when the remotely transmitted signal (frequency modulated by the data to be transmitted) is mixed with the local transmitter. Each end uses its own transmitter as a receiver local oscillator, and each unit transmits continuously. Therefore, each receiver sees the same IF. This is the same full duplex arrangement used for many years by Amateur microwave enthusiasts. The transmitters run 5 to 10 mW of output power. The transmitter is frequency modulated as its bias supply is varied and the frequency-voltage dependency of the transceivers is used for tuning. This same technique was used previously to phase lock such oscillators.[1] The 2-foot dish shown here has a gain of about 33 dB, or 2000 times at 10.5 GHz. When driven by the microwave transceiver, the effective radiated power (ERP) is about the same as that of a 10-watt 2-meter radio driving a quarter-wave whip. We selected 105 MHz for the receiver first IF, with provision for tuning ±10 MHz to accommodate differential frequency drift with time or temperature of the free-running microwave transceivers. Using an IF in this range also lets you do some simple troubleshooting and testing with commonly available commercial FM broadcast receivers. No correction is necessary if both ends drift in the same direction because the IF doesn't change. Automatic Frequency Control (AFC), implemented by tuning the second LO nominally at 150 MHz, is provided to keep the receiver tuned correctly. This conversion produces the second IF at the point where detection takes place at 45 MHz in a Motorola MC13055 FSK receiver chip. This chip is specified to operate at data rates up to 2 megabytes per second (Mbps), but has actually been used as high as 10 Mbps.

Automatic frequency control circuits keep each receiver correctly tuned, even when the first IF deviates from 105 MHz. A search oscillator is also provided to allow the receiver to "find" the incoming signal when the link is first powered up, or if you lose signals temporarily. The searching is controlled by the Data Carrier Detect (DCD) circuitry. Once the signal is found, the oscillator is shut off and the AFC tunes the receiver correctly. Because the data is digital, an appropriate offset is introduced to the tuning depending on whether the data is a "0" or a "1." We added the audio channel as an afterthought. It provides for human communication, particularly while debugging the link and operating it with digital data the first time. An electret microphone produces the transmit audio signal. This is amplified and limited by high and low pass filters before modulating the transmitter. Levels were selected to provide only small deviation compared with that of the digital channel. This allows the audio channel to operate without significantly interfer-

FIGURE 2A



Mechanical layout of the 10-GHz dish feed and mounting system.

ing or degrading the digital data. A volume control and speaker amplifier sufficient for driving headphones or a small speaker are provided on receive.

An analog meter displays strength as carrier-to-noise (C/N) ratio or discriminator output to aid when manual frequency control (MFC) is used. The MC13055 FSK receiver chip has a built-in logarithmic amplifier which can give a pretty accurate measure of C/N. A switch lets you select manual or automatic frequency control.

The microwave transceiver, modulator, and receive preamplifier are mounted together in a box located at the prime focus of the parabolic antenna. A horn antenna was designed to illuminate the dish antenna efficiently so that near maximum gain could be obtained. The rest of the receiver, as well as circuits for the audio channel, are located in a separate enclosure. This lets you place the antenna and microwave hardware a considerable distance from the receiver for tower or mast mounting.

We used Emitter Coupled Logic (ECL) for incoming and outgoing data. These are differential lines and can be used even when there is considerable line length — for example, when the microwave portion is high on a tower or the receiver is located some distance from the host computer. A standard 15-pin connector is used as the interface to the radio hardware. Those familiar with Local Area Networks (LANs) may recognize this connector and pinout as identical to that of a Media Access Unit (MAU), the device used to link a computer to a coaxial cable connecting a building or area wide network. You need just 12 volts DC at approximately 350-mA data input and data output to operate all the radio link hardware.

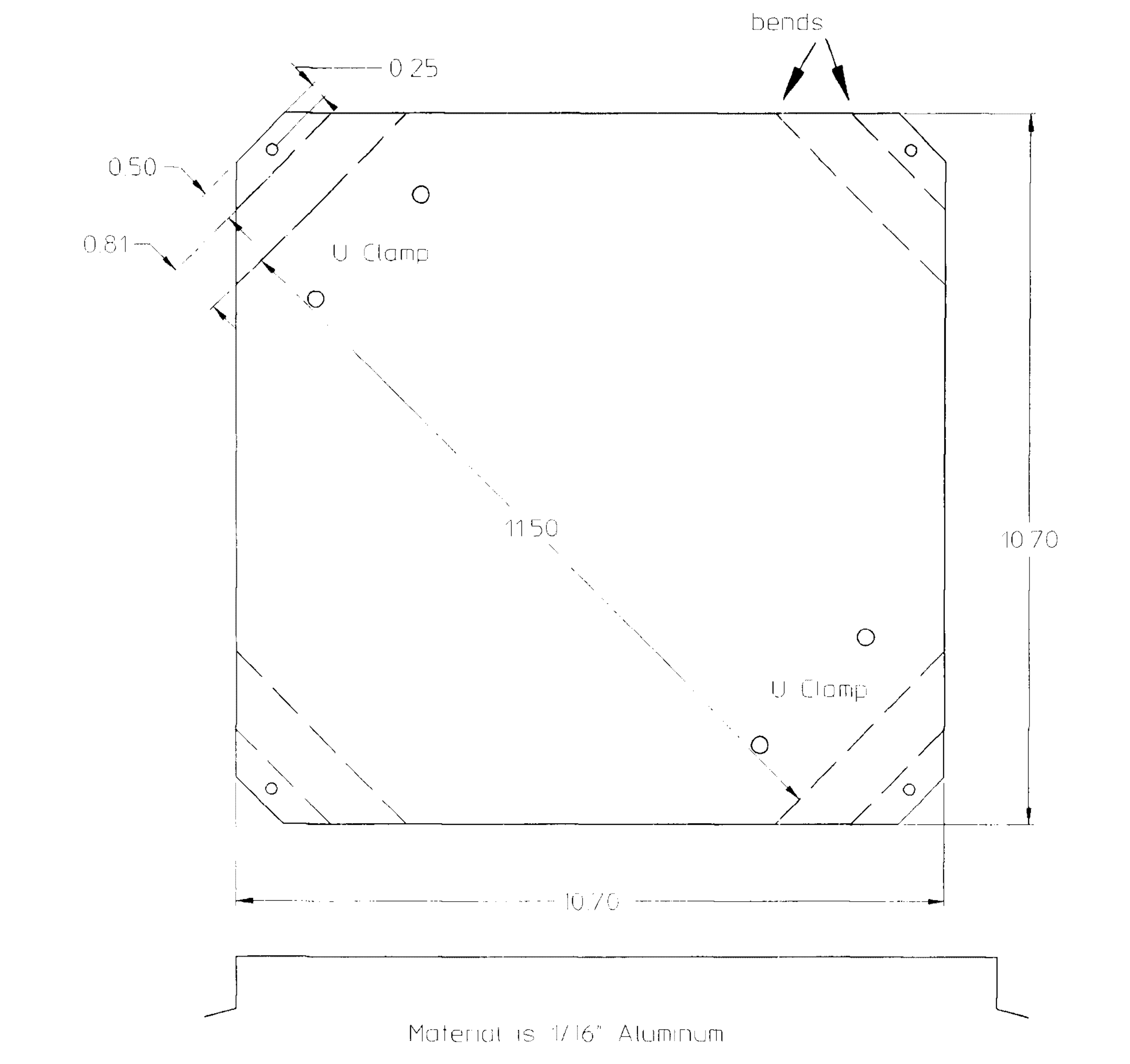
Antenna

The antenna is mounted to a mast with a rear mounting bracket. This plate is cut from sheet aluminum and folded to produce four "feet" which attach to the dish. Mount the plate to the mast with U clamps. For minor elevation steering of the antenna, add two extra sets of nuts to the clamps.

(continued on page 17)

(continued from page 12)

FIGURE 2B



Dimensions of the feed support struts.

This lets you adjust the spacing between the mast and plate. Less spacing on the top than on the bottom clamp points the dish upward; more spacing points it downward. Because the antenna has less than a 4-degree half-power beamwidth, you may need to make this adjustment — particularly when the two ends of the link are at different elevations and not very far apart.

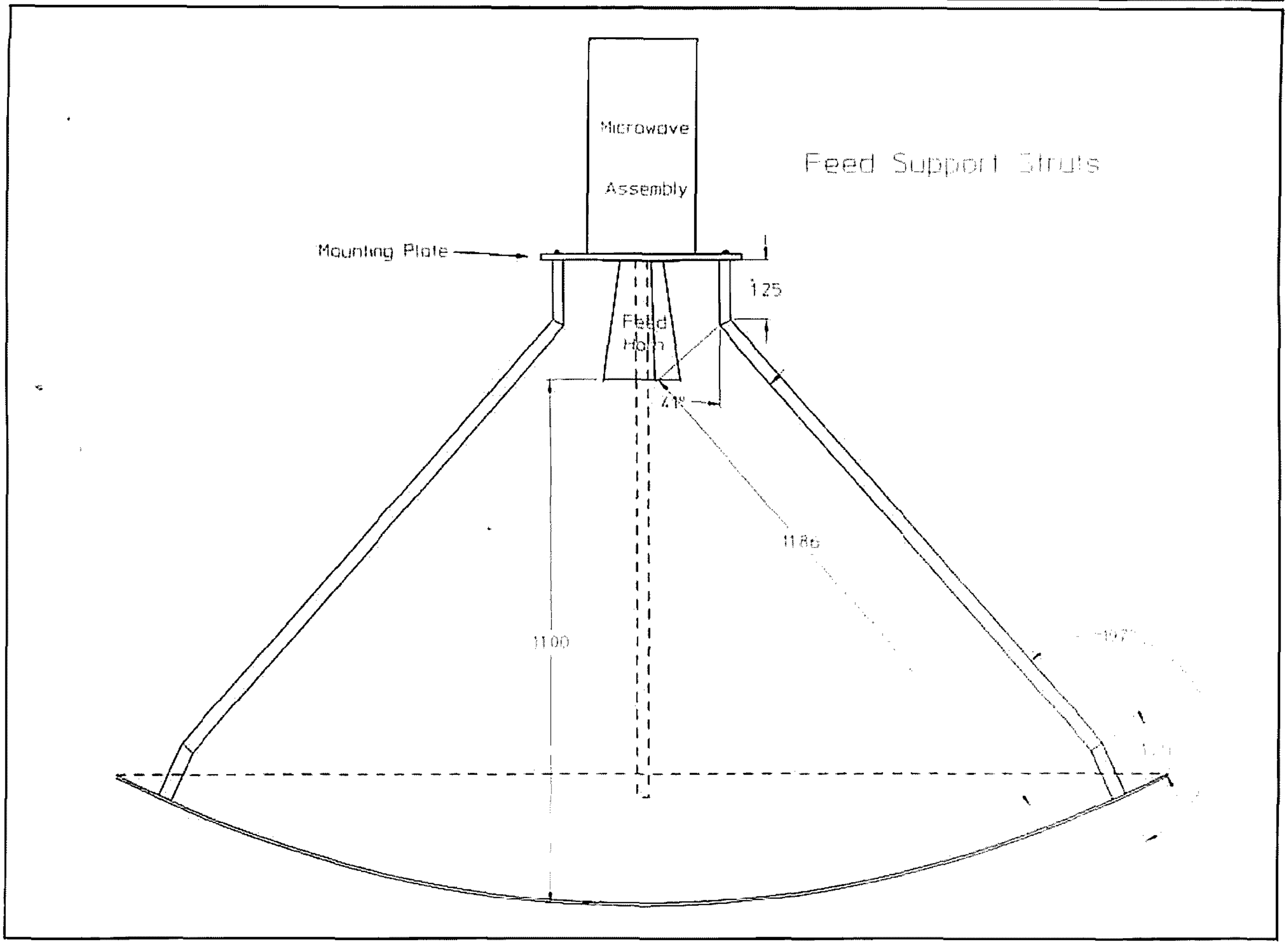
The horn feed and microwave assembly attach to a plate and are held at the dish focal point by four 1/4-inch diameter struts made from soft aluminum rod. We found this material at a local home supply store. First cut the aluminum rod to length; then drill and tap it at each end. Use a tubing bender to shape the rod properly. **Figures 2A, 2B** and **3** show the mounting bracket and feed support struts, respectively.

Feedhorn

To construct the feedhorn, first cut the sides and flange from copper or brass shim stock as shown in **Figure 4**. Because the material is so thin, you may want to begin by tacking the whole assembly together using a medium sized soldering iron and complete your soldering after everything is in place.

The feed/microwave assembly is shown in **Photo A**. The mounting plate has a short section of waveguide at its center. The feedhorn and transceiver mount on opposite sides and a small Bud box encloses the electronics. Make the waveguide section by milling (or drilling) and filing a 0.40 by 0.90-inch rectangle in the plate. Great precision of construction for either the feed or the mounting plate isn't

FIGURE 3



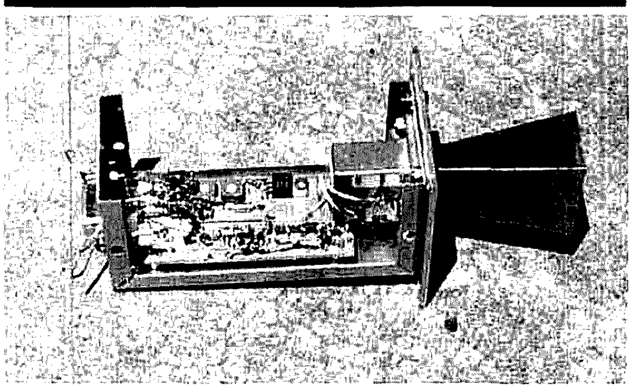
Dimensions of the feed support struts.

necessary to obtain good performance. Figure 5 shows the feed mounting plate.

Microwave assembly

Because the microwave transceiver is self-contained, the RF electronics aren't particularly critical or difficult to assemble. The receive preamplifier is probably the only sensitive circuitry, and because this uses MMICs, short lead length and good grounding are the only prerequisites. If you use pc board material, you can make the entire board using a file and small hobby knife. Fifty-ohm transmission line is used to connect to and from the MMICs. Try making this line by filing 0.005 to 0.010-inch slots 0.1 inch apart. The line can then be cut into short sections and the components soldered directly to it. Holes drilled in the board allow the MMIC packages to sit flush with the lines. Holes are also drilled for all component ground leads, and the leads are soldered on the top and bottom of the board. The regulator and modulator circuits aren't critical and the ECL IC may be "dead bug" mounted on top of the board. You can mount the board to the aluminum box with short spacers. Use a twisted pair made from hookup wire to connect to the mixer diode on the transceiver. Figure 6 shows an approximate board layout. (See Figure 7 for enclosure dimensions.)

PHOTO A

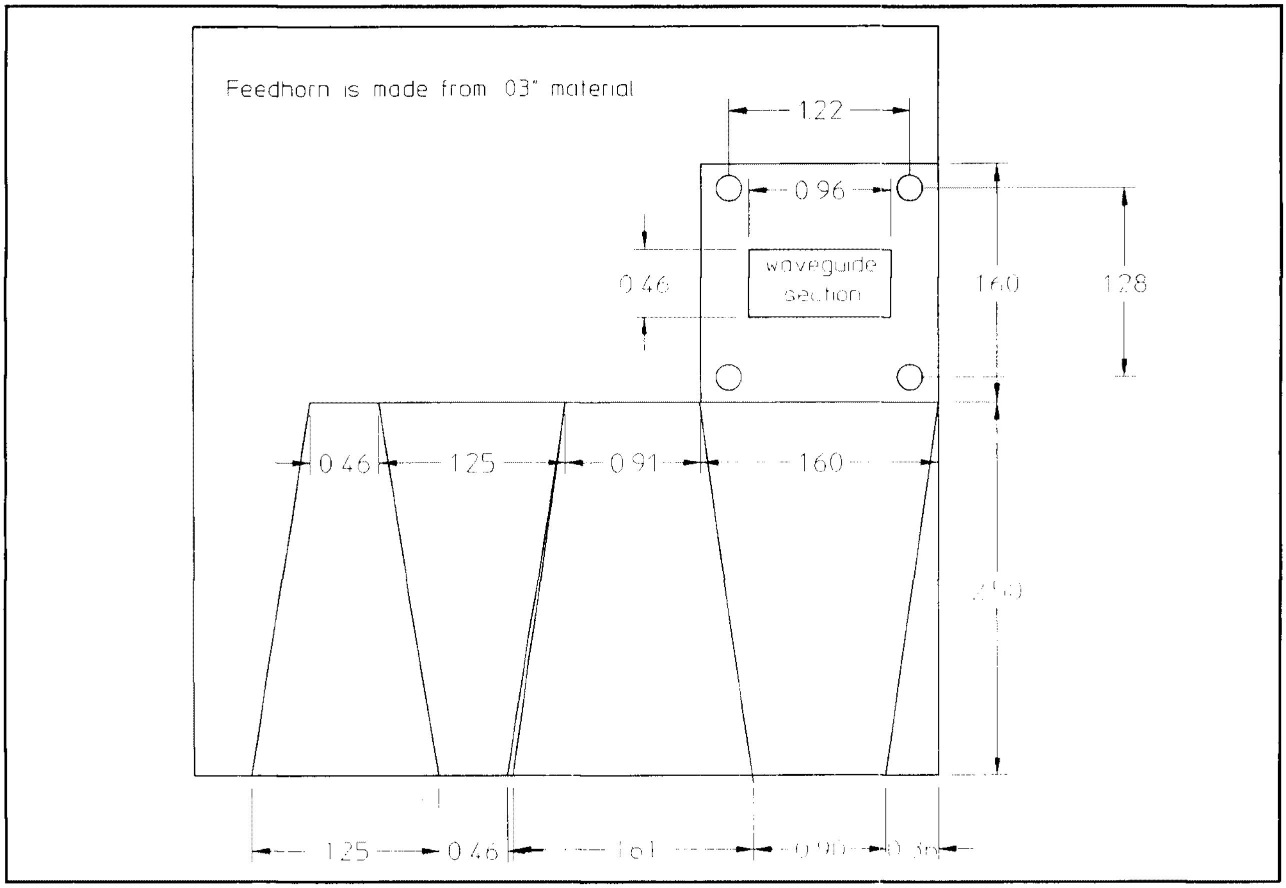


Feed/microwave assembly.

Receiver assembly

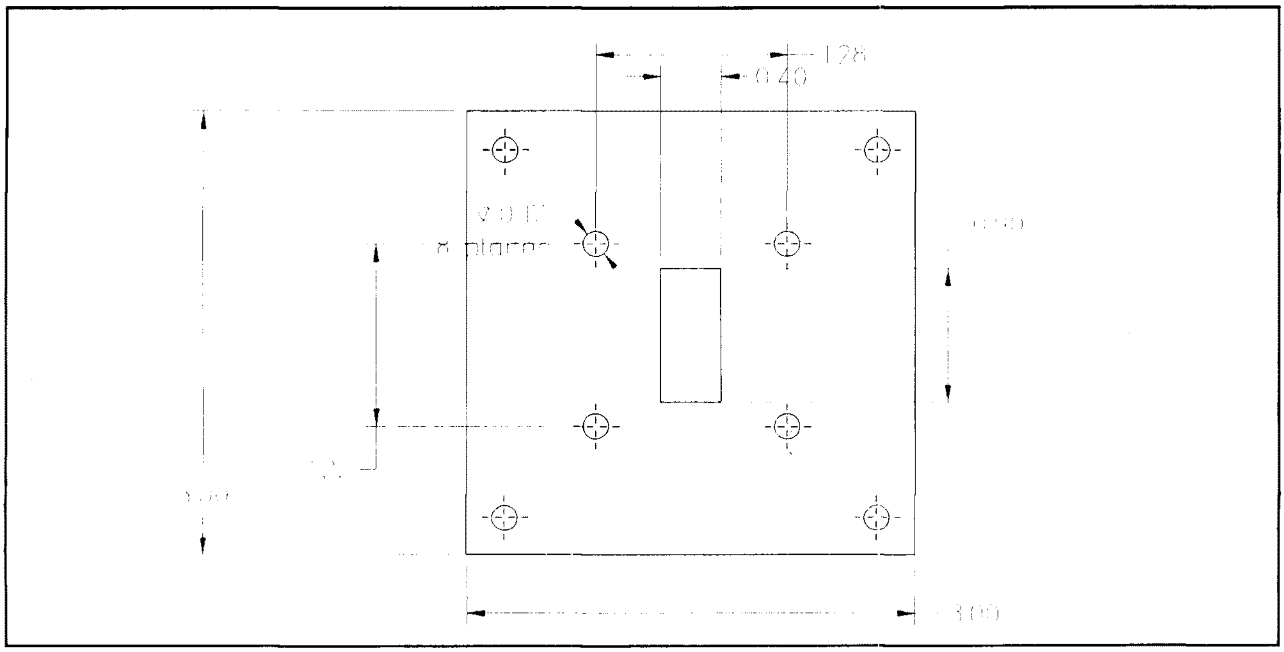
Receiver assembly construction also isn't critical. See Figures 8A through 8C for details. Use ground plane as much as possible on the component side of the board and keep traces to the 45-MHz filter and discriminator reasonably short. Otherwise, no special precautions need be

FIGURE 4



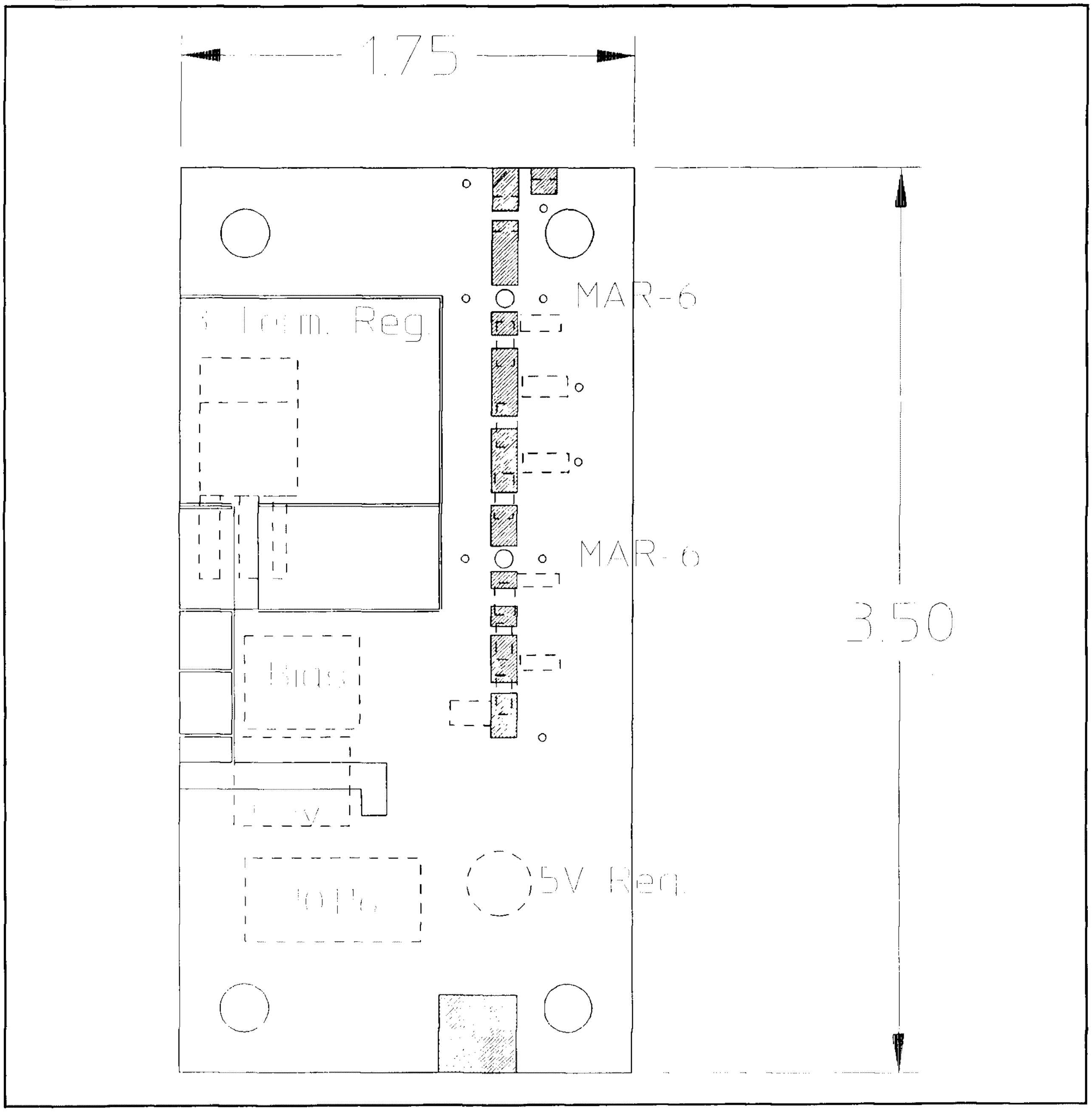
Dimensions for feedhorn construction.

FIGURE 5



Microwave assembly/feed mounting plate.

FIGURE 6



Preamplifier/Tx modulator board component layout.

taken. All ICs may be socketed for convenience. (PC layout or circuit boards may be available by press time. Contact the authors for further information. Ed.)

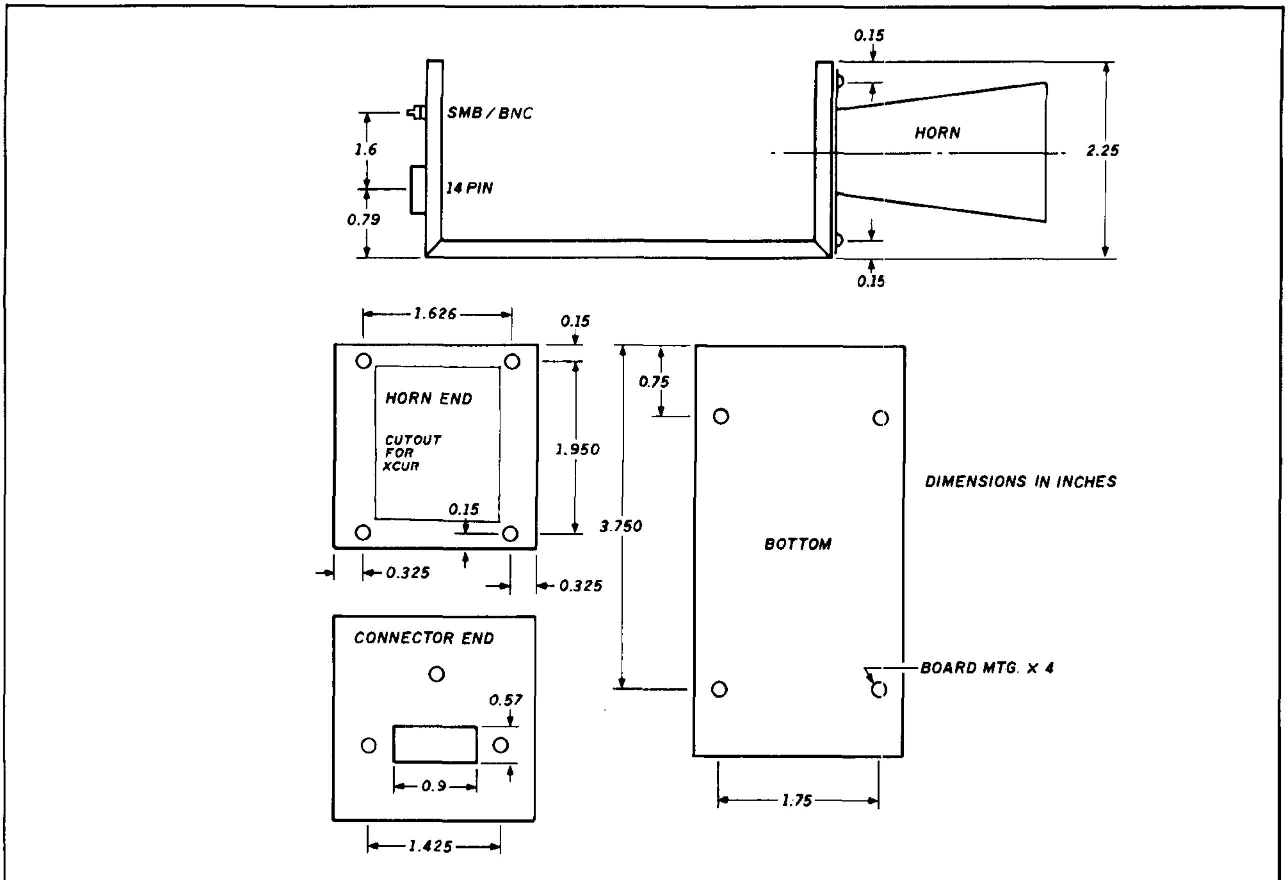
Computer interface

We chose the IBM PC as the initial platform for developing and testing faster packet hardware. The IBM PC is generally available and affordable, with sufficient capability and adaptability. The IBM PC is the defacto standard for people pursuing higher speed packet. The bus architecture is well known, and there are a large number of experts to consult should you encounter problems.

The original system design called for standard off-the-shelf Ethernet™ adapter cards. Normally Ethernet lets a number of computers intercommunicate within a local area at a data rate of 10 Mbps. N3EUA suggested we use the same widely available cards and the associated IEEE 802.3 protocol with the adapter card clocks slowed to 1 Mbps. Using a standard Ethernet adapter gives you access to an existing range of networking software, including NetBios/PC Network and TCP/IP implementations. It's an interface familiar to the general ham community, one that the advanced packeteer probably already knows and works with.

Stock Ethernet cards can't be slowed from 10 to 1 Mbps

FIGURE 7



Dimensions of the box to house the microwave circuitry.

without extensive reworking. The serial data interface portion of the cards must produce a clock rate within 0.001 percent of 10 Mbps to conform to the IEEE 802.3 specification. By the time we discovered this we had working "RF bit pumps," but found ourselves without a suitable digital interface.

Several years ago IBM produced a digital communications adapter known as the PCLANA or SYTEK 6120. This adapter was designed to communicate using FSK signals transmitted on a coaxial cable at a 1-Mbps rate. The card implemented Ethernet framing with a NetBios interface directly on the card. The card consists of a local μP (80186), an Ethernet chip (82586), custom 802.3 serial data interface, RAM, ROM, PC bus interface, and an RF modem. While the RF modem is interesting, it was unnecessary for this project and was disconnected.

We discovered that this card had all the right pieces: 1-Mbps Ethernet frames, defined PC interface, and because 10-Mbps Ethernet was displacing these cards, good availability on the surplus market—sometimes just for the asking.

To use the PCLANA card, we needed to gain access to the TTL signals directly (before modulating the RF modem), build an adapter card onto the PCLANA for converting TTL to differential ECL, generate DCD, and route Transmit Data (TxD) and Receive Data (RxD). You'll need a software driver if you want something other than a NetBios interface. A schematic of the card is shown in the *IBM PC Technical Reference Manual*, "Options and Adapters" section.

How the adapter card works

A "daughter" adapter (**Figure 9**) is fitted to the PCLANA to take the TTL TxD, RxD, DCD, and RTS. It produces a valid interface to the microwave RF modem, including power and differential ECL interface.

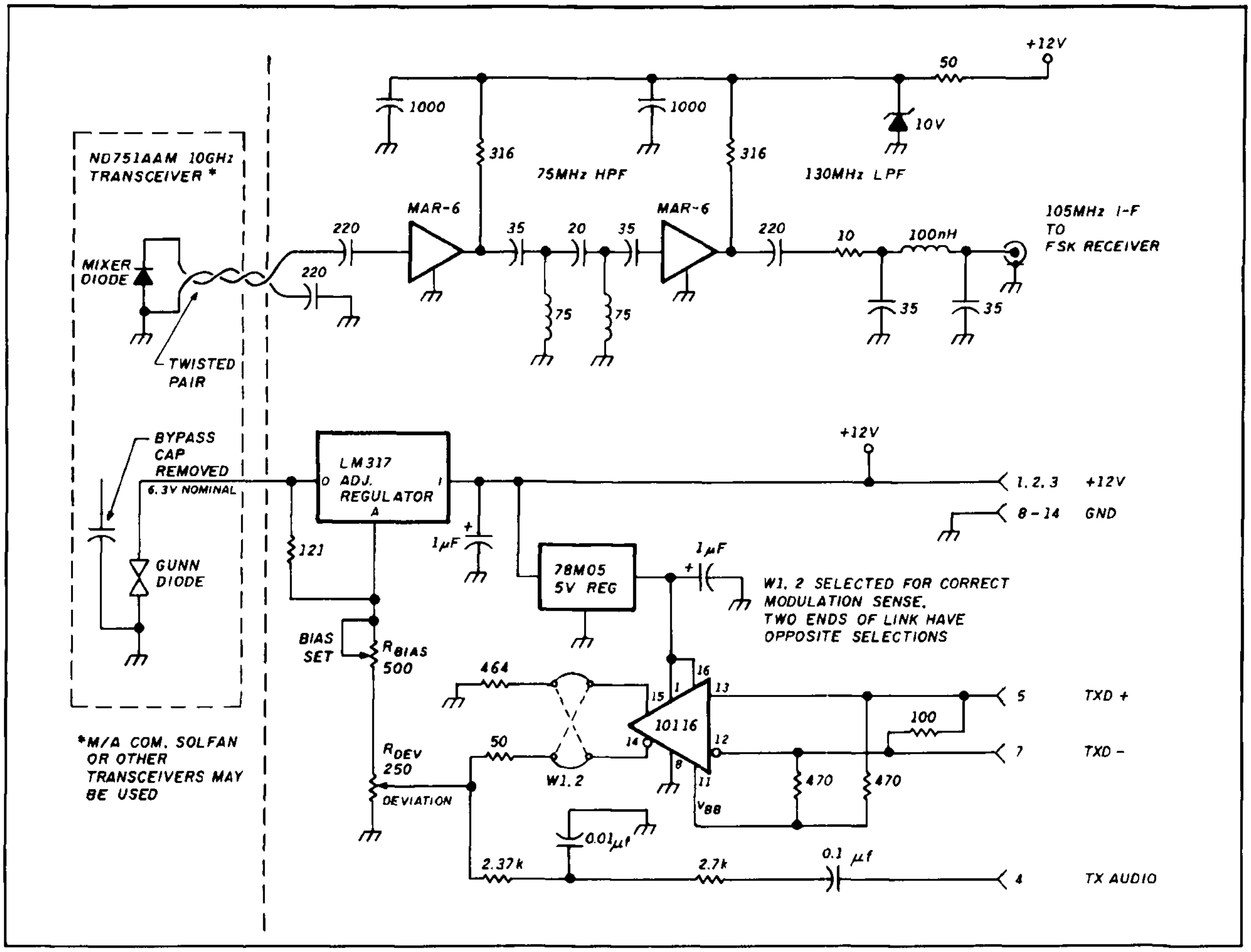
The microwave modem interface closely matches the IEEE 802.3 MAU which normally connects the digital interface to a coaxial cable. A MAU is also known as an Ethernet transceiver (XCVR). We chose this interface because it allows long (120 foot) cable runs, good common mode noise immunity (0.6 volts), and a standard interface.

TxD is converted to differential ECL levels with an open collector (OC) NAND gate and a resistor totem pole. This produces the right voltage level for one end of an MC10116 differential line driver input. The other differential input is tied to the MC10116 Vbb. The output of the MC10116 is differential ECL. Because the ECL drivers are open ended, each line is pulled to ground with a 470-ohm resistor. The polarity of ECL lines to the pins of the DB15 connector is important. Switching these lines will result in a bit sense inversion.

RxD is converted from differential ECL to TTL using the differential drive from an MC10116 biasing the base emitter junction of a 2N3906 PNP transistor. This drives a standard TTL NAND input.

TxD is qualified by Ready to Send (RTS) from the

FIGURE 8A



The schematic for preamplifier bias and modulation.

PCLANA (U1b). This is necessary because the SYTEK SIC doesn't clamp the TxD line to logical zero when RTS goes false.

The SYTEK SIC interface chip is designed to work on a cable with multiple stations. It monitors the DCD line, and if it finds that it has been true too long, the SIC declares the cable jammed. Because the microwave RF modem provides continuous DCD with or without data, we used a retriggerable one shot (U2a) connected to the incoming RxD signal to generate an appropriate noncontinuous DCD. On the first low-to-high transition, DCD will be asserted and the one shot will start timing. Each low-to-high transition in the incoming data will retrigger the one shot and keep it from expiring. When data stops and the RxD line clamps to a low, the DCD will fall to a zero when the one shot expires. Because each end of the link expects to hear itself, the DCD is ORed with the local RTS (U1a).

Building the interface adapter and PCLAN adapter modification

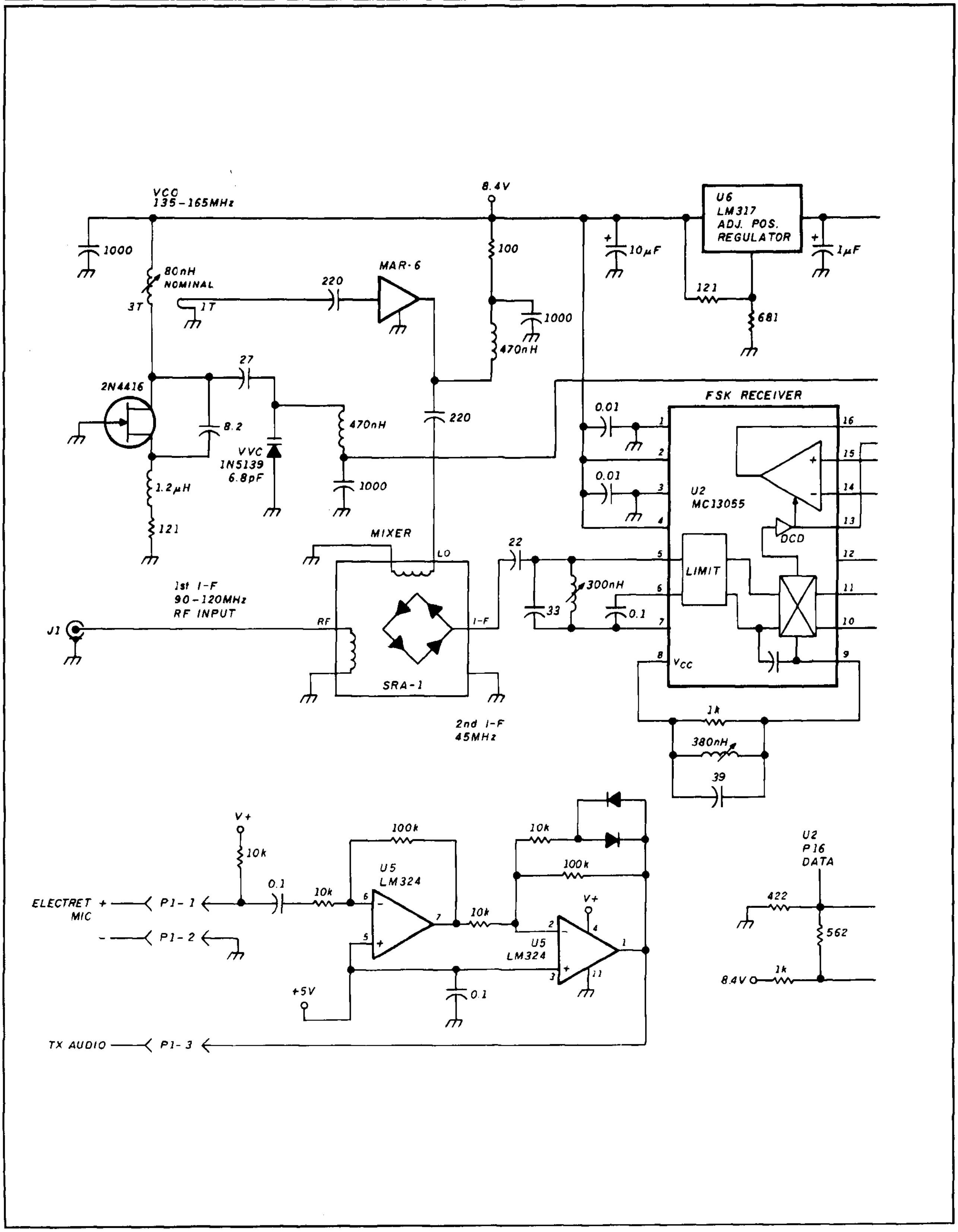
Adapter card construction is straightforward and can be completed quickly with IC sockets, perfboard, and point-to-point wiring. The entire circuit runs at baseband speed, so layout isn't important. (Contact the authors if you want a pc board layout.)

The PCLANA modification can be simple or time consuming, depending upon how elegant you want the finished project to be. The adapter daughter board must be mounted on the PCLANA. The best place to do this is over the long metal cover housing the actual RF modem. Decide on a place and prepare your mount.

You might consider removing enough of the RF modem components to make room for the daughter adapter board. If you do, be aware that the RF modem reports to the onboard µP (80188) as to the validity of the −12 volt DC power line (for historical reasons). If you remove the RF modem without connecting this signal, the µP will report an error whenever you attempt any operation. Locate Q20 and R121 on the left side of the pc board next to the lower left corner of the RF modem cover (if it's still installed). The left end of R121 is tied to the base of Q20. Cut the trace to the right end (or unsolder R121) and reconnect it directly to −12 volts DC on the board (bus pin B7).

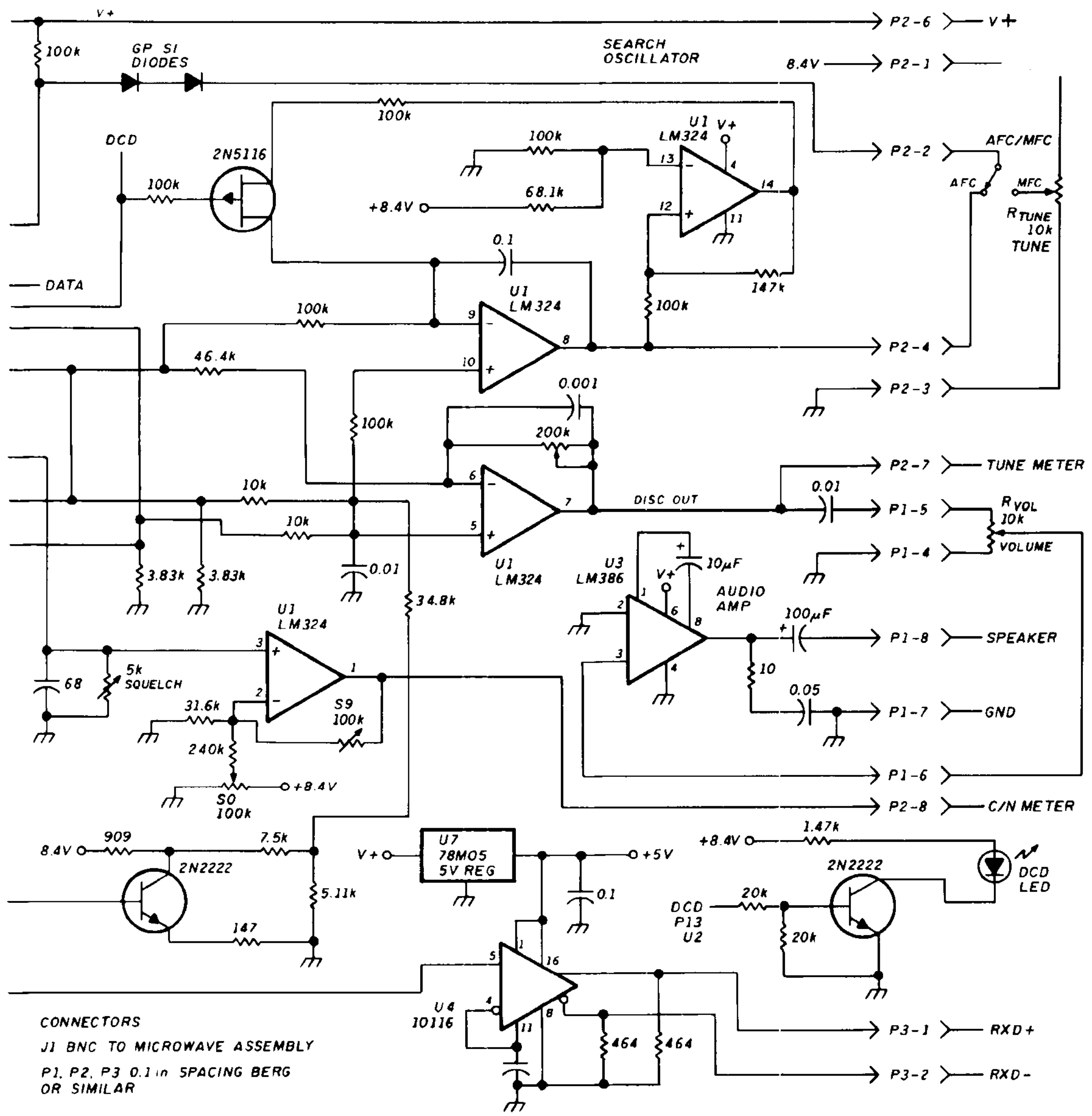
You need four signal lines to connect the daughter card to the PCLANA. They are: TxD, RxD, DCD, and RTS. You also need three power lines: +5 volts, +12 volts, and GND.

FIGURE 8B



The receiver portion of the transceiver.

FIGURE 8B


V+
100k
GP SI
DIODES
SEARCH
OSCILLATOR
8.4V
P2-6
V+
P2-1
DCD
2N5116
100k
U1 V+
LM324
100k
68.1k
+8.4V
P2-2
AFC/MFC
AFC
MFC
R TUNE
10k
TUNE
0.1
DATA
147k
100k
U1
LM324
46.4k
P2-4
P2-3
0.001
200k
100k
P2-7
TUNE METER
10k
DISC OUT
0.01
P1-5
R VOL
10k
VOLUME
10k
P1-4
3.83k
3.83k
0.01
U1
LM324
U3
LM386
10µF
AUDIO
AMP
34.8k
100µF
P1-8
SPEAKER
U1
LM324
68
5k
SQUELCH
S9
100k
10
0.05
P1-7
GND
31.6k
240k
+8.4V
S0
100k
P1-6
P2-8
C/N METER
909
8.4V
2N2222
7.5k
V+
U7
78M05
5V REG
+5V
+8.4V
1.47k
2N2222
DCD
LED
5.11k
0.1
DCD
P13
U2
20k
20k
147
U4
10116
464
464
P3-1
RXD+
P3-2
RXD-
CONNECTORS
J1 BNC TO MICROWAVE ASSEMBLY
P1, P2, P3 0.1 in SPACING BERG
OR SIMILAR

You'll find the connection to ground underneath the screw holding the mounting bracket to the rear of the card. Postive 5 volts DC is taken from a trace leading to edge connector A1 (component side of the card, on the right). Positive 12 volts DC is also taken from a trace leading from B9 (solder side of the card, on the left). This trace also "comes through" to the component side of the card and is easier to solder to. The current demand is low, so you can make contact by cleaning a portion of a *wide* trace, tinning it, and soldering to it.

Make signal connections to the SYTEK SIC chip by bending pins up out of the socket and soldering to them. Find IC U16 in the upper left of the board. It's designated SIC and is a wide 28-pin device. Pin 1 should have a red dot and be on the lower left. Remove the device carefully; you probably won't be able to find a replacement easily. Bend pins 12, 13, 17, and 18 up so they won't make contact with the socket when the IC is reinserted, and so you can solder to them. Reinsert the IC. Connect the daughter board signal leads directly to the exposed leads. Pin 12 is RxD, 13 is DCD, 17 is RTS, and 18 is TxD. It's a good idea to use shrink tubing on each lead. Be careful not to heat the device unnecessarily while soldering.

With the daughter card mounted on the PCLANA and all seven interface lines hooked up, measure the resistance from the +5 and +12 lines to GND. Find the cause of any reading less than 700 ohms before installing the card in the PC.

If everything checks out, install the board in a PC bus slot and power up the computer. If the microwave hardware isn't attached to the 15-pin daughter board connector, the PC will delay for about 15 to 45 seconds during the boot cycle. It may display an error 3015.

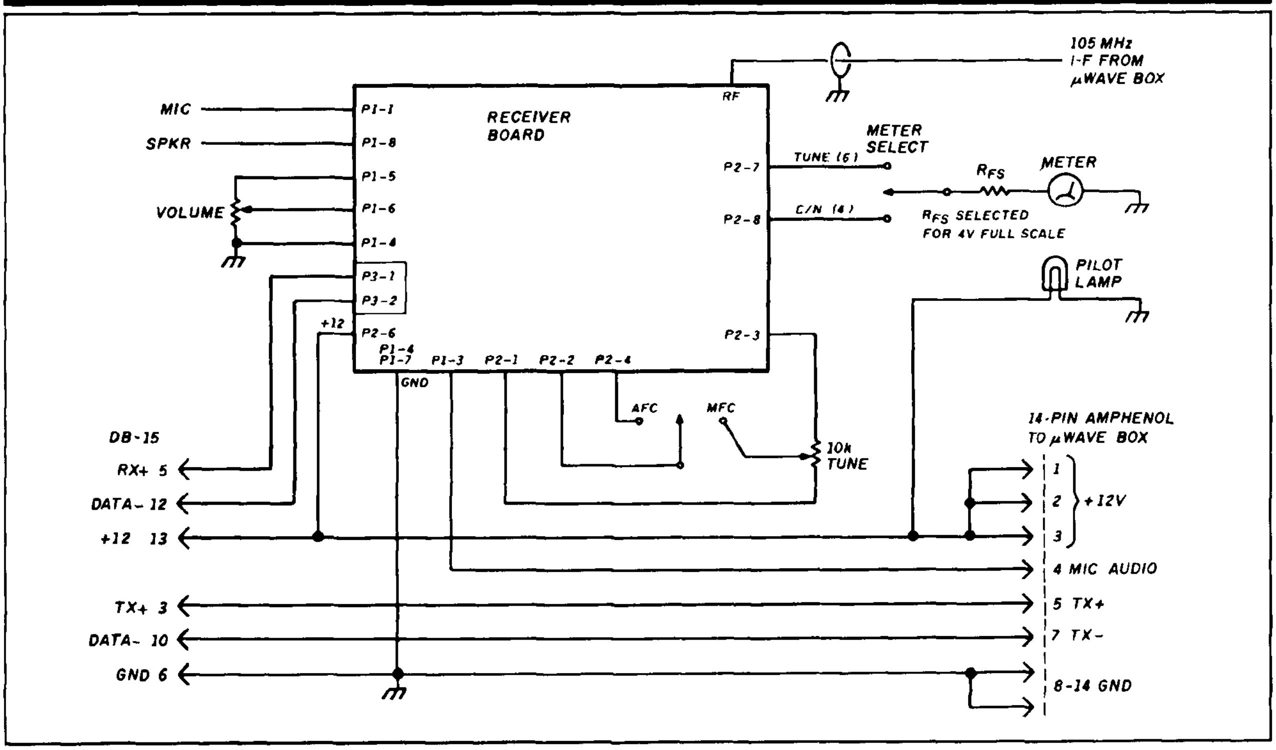
To complete testing, install a similarly modified card in another PC, connect the microwave hardware, power up both computers, and check to see that both FSK receivers show DCD. It may be necessary to reboot the PC by selecting *ctl-alt-del after* DCD has been established. When the PC is booted, the PCLANA runs through a series of diagnostics which include frame loopback. The loopback will fail if the microwave hardware doesn't have DCD. Depending on the PC, the PCLANA card will declare itself inoperative until you run diagnostics again.

If you have a copy of the IBM PC network program, you can now start it on both machines and share disks. Playing with the network can provide lots of creative fun. With the link running to a fellow ham, you can access each other's hard disks. Suppose you just finished some nice graphics and you want to show them off. Instead of reaching for your ATV camera, bit dump the screen image to disk and do a DOS copy file from your disk to your friend's. Your friend will be able to see your work in seconds. A driver is also available to provide packet interface support for Phil Karn's (KA9Q) TCP/IP package for the PC. (Contact the authors for further information.)

Tune-up and testing

Unless you have a 10-GHz microwave signal generator available, you should build these units as a pair — although two dishes aren't necessary for short range use or testing. You should build the microwave assembly and set the bias voltage from the three-terminal regulator to approximately

FIGURE 8C



The transceiver interconnect layout.

6.3 volts before connecting to the transceiver. Verify that the deviation control can be set to give 0.25 to 0.5-volt variation when the ECL line receiver is toggled between states. Once the biases are correct, hook up the transceiver. Most transceivers as shipped will be close to 10,525 MHz. With two transceiver/horn assemblies pointed at each other and separated a few feet, hook a frequency counter or general coverage receiver to the preamplifier output. Leaving one unit's tuning unchanged, tune the second unit while monitoring the IF frequency with a counter or listening for it in a general coverage receiver. Turning the mechanical tuning screw further into the cavity will reduce frequency. As the unit is tuned 70 MHz (or more) lower, you should be able to read the difference in frequency with a counter. You should be able to "walk" the two units lower in frequency into the hamband using this technique and space them 105 MHz apart. If you get "lost" and don't know the absolute frequency, try using a local supermarket door opener as an approximate 10525-MHz reference. If a microwave frequency indicator is available, adjustment is trivial.

Once the two ends are operating 105 MHz apart, you can align the receivers. Select MFC and midrange control setting, and use a counter or 2-meter receiver to monitor the VCO frequency. Set it to 148 to 150 MHz at midrange. You should be able to tune several MHz on either side of this center with the manual tuning control. You can use AFC to tune it even further once the other circuits are operating. Tune the VCO to 45 MHz above the previously measured frequency of the microwave IF and adjust the 45-MHz bandpass coil for maximum C/N reading. It may be necessary to separate the units or use conductive foam material to keep the signal strength reading on scale. Once the receiver is peaked on a 45-MHz IF, tune the discriminator coil to center the detector output voltage on pin 10 or 11 of the MC13055. With the squelch control set to maximum resistance of 5 k, a 0.35-volt change on pin 12 corresponds to 10-dB change in signal strength. Keeping the receiver tuned to center with MFC, adjust the position and absorbers to produce about 10 dB of C/N. Then adjust the squelch control so the DCD light just extinguishes. Measure the squelch control resistance again and calibrate your C/N reading by calculating sensitivity:

$$V(p12) = 0.070 * Rsquelch \qquad (1)$$

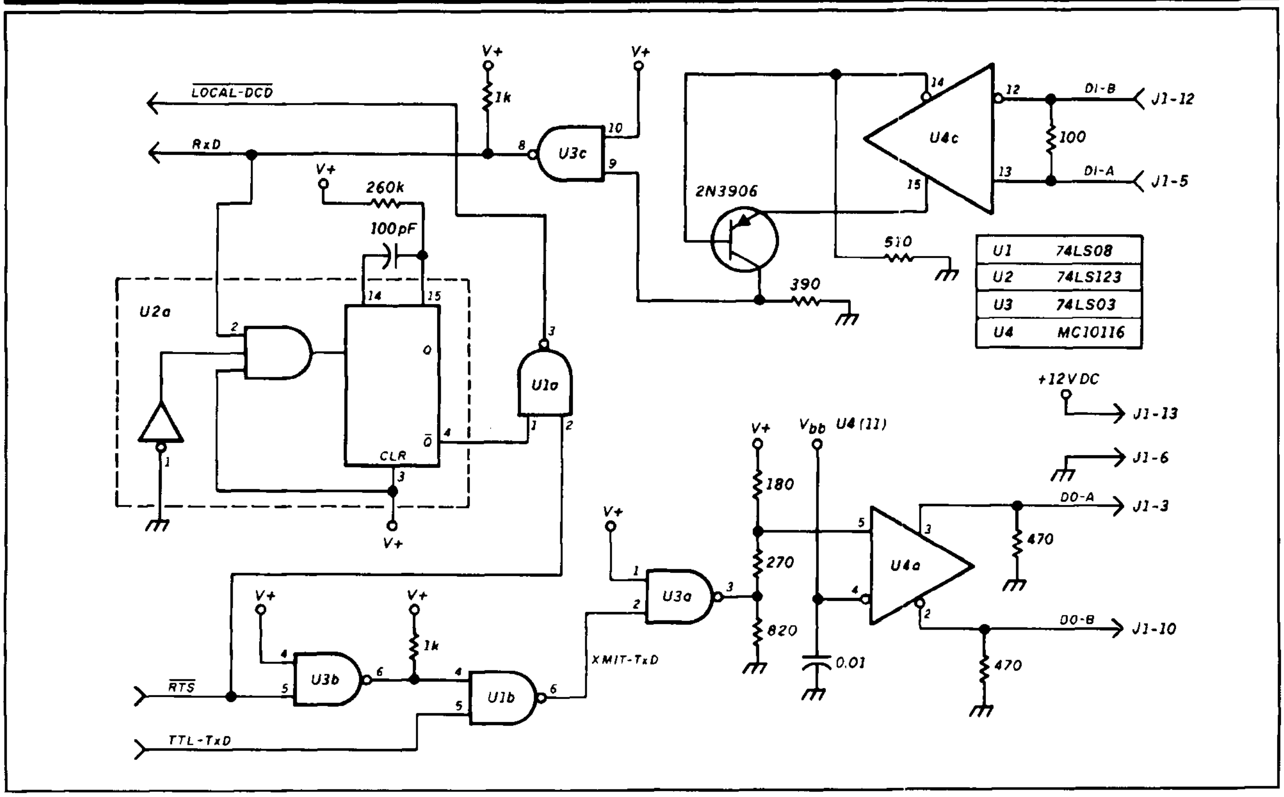
Rsquelch = squelch resistance in kilohms.
V(p12) = voltage change at MC13055 pin 12 in volts for 10-dB change in signal.

Adjust the discriminator output sensitivity to give full scale on your meter as you use the MFC to tune across the incoming signal. Finally, verify that the search oscillator runs when you select AFC and that there's no incoming 105-MHz IF signal. This should appear as a sawtooth oscillation on the VCO tuning line.

The audio channel should work without further adjustment. Some background noise may be audible even when signal strength is high due to the phase noise of the microwave oscillators, but the level shouldn't be objectionable.

Use an oscilloscope to verify data throughput and correct transmitter deviation setting. Monitor the discriminator out-

FIGURE 9



Adapter board for the PCLANA card.

put with the scope and set the scope sensitivity to give full screen display as you use the MFC to tune through a signal. When you reach this stage, the transmitter may be modulated with data and the deviation adjustment may be used to set the discriminator output to slightly less than full screen. It may be necessary to iterate with the bias setting to keep the transceiver bias centered on 6.25 volts.

At this point, both the transmitter and receiver should be functioning properly and may be used for audio or digital communications. When units are separated by a great distance, or signals are otherwise weak, it may be beneficial to monitor the audio channel as an aid to link adjustment. Audio communication will be possible even when noise is causing excessive errors on a data channel.

Performance, results, and remaining problems

Getting data to flow on the bench led to a couple of surprises. While debugging the software drivers, we learned new elements of timing relationships. Since this is point to point, and the only start-up delay is software latency (no hardware TXDELAY), data frame ACKs arrived from the other end before we'd finished processing the send request. Pieces of software that were just fine at lower speeds had to be rethought and streamlined to achieve throughput.

Aligning the microwave dishes requires some skill. If you haven't done this before, allow plenty of time for alignment, have solid mounts, and don't expect it to be like 2-meter work. Use the audio channel to listen for receiver quieting and get a feel for the narrow beamwidth. Don't try to hand hold the antennas at both ends; both must be pointed correctly before either end hears anything. It may be useful to use manual frequency control at first. If you can put one end of the link at a high elevation temporarily, you can power the other end from 12 volts DC in your car and drive around to see what microwave communication feels like. The experience you gain doing this will help to make you a good judge of final locations for the digital link. Because these are low budget systems, line-of-sight transmission is probably necessary for anything other than fairly short links. An exception would be if a good planar reflector were located close to one end and used as an efficient mirror. You can try this technique to keep the hardware at ground level using a mast or tower-mounted "billboard" reflector. This has environmental advantages for the hardware, too.

Measurements indicate that the unit passes data with a low bit error rate (BER) down to signal strengths below 15-dB C/N. It's important to use direct paths; severe distortion can occur when multiple paths exist between the ends of the link. Such multipath conditions can cause link failure, even with very large C/N. This sensitivity should provide low error data transmission on a line-of-sight path of more than 40 miles with well-stirred air. In many locales, marine air layers and other causes of fading and ducting may require shortening the path to guarantee high linkup time.

With the link installed at two locations 13.5 miles apart in northern California, C/N measurements show that there is at least 10 to 15 dB more signal strength than the minimum necessary. This indicates that more than 40 miles should be possible with this hardware as shown. However, because longer paths are more likely to experience propagation anomalies and heavy rain could decrease signal strength temporarily, it's desirable to use slightly larger dishes for longer paths. The audio link has proved useful in system troubleshooting too.

As with any ham project, there's certainly room for improvement. Because the original RF design was for a 2-Mbaud link, you should be able to improve DX by optimizing the receiver detector bandwidth. If you operate with a mast, the equipment needs to be waterproofed for all-weather use. As an alternative, you could mount a coax waveguide adapter to the feedhorn and locate the microwave circuitry remotely in a more protected environment. Use low loss semi-rigid coax cable for connecting to the antenna if you do so. A suitable coax waveguide adapter was described in an earlier article.[2]

If you want to use them, almost any of the surplus radar detector, motion detector, or burglar alarm Gunn transceivers should work well. M/A-COM Gunnplexers™, although somewhat more expensive, will work too. They have built-in electronic tuning that permits modulating at higher rates for full 10-Mbaud data links or ATV uses. It should be possible to frequency modulate them by driving the electronic tuning input from the ECL output, properly scaled and offset with a resistor network.

The first prototype of this link was built using 24-GHz radar transceivers and metal lamp reflectors for antennas. This arrangement works very well. Because of the modular system design, you may substitue these microwave assemblies for the 10-GHz ones described here without making any other adjustments. The higher gain available for a given dish antenna size at 24 GHz can actually provide better performance over some paths.

You can use a larger antenna for greater DX or more difficult paths. If you use something other than a 0.5 F/D reflector, you'll need to design a new feedhorn to produce maximum performance. Other diameters are available from the indicated supplier.

Where to go from here

Ham radio has often made use of surplus and obsolete gear. Many have designed and built their own equipment. This project is no exception. By the time you read this, there will be a PC card (designed primarily by K3MC) capable of two-channel, full-duplex 2.5-Mbps operation. You'll be able to split the channels into four half duplex if you wish. The card will have a V40 μP, RAM, and Zilog 85C30 SCC devices, plus the usual glue logic. Bit rate will be software selectable. The card will have enough capacity to run as an IP router, allowing the PC to perform other functions while continuing to provide network access.

We are also working to build inexpensive 250 to 500-Kbaud 900 and 1200-MHz radios to give the individual user access to other hams and to a "backbone," using this higher speed microwave hardware. We hope to have a fledgling moderate speed network in place in northern California and Colorado by the time this article goes to press. As the hardware is put into place, the platform for some really exciting applications and a whole new era of Amateur Radio becomes a reality.

The authors would like to thank WN6I, N3EUA, K3MC, and N6TTO for their encouragement and perseverance during testing. We'd also like to thank our XYLs, Sharon and Lynn.

Suppliers

Most of the components for this project should be available from:

Digi-Key Corporation
701 Brooks Avenue South
Thief River Falls, Minnesota 56701, 0677

The antennas are available from:

The Antenna Center
505 Oak Street
Calumet, Michigan 49913 (906)337-5062

The microwave transceivers shown are NEC ND751AAM, which may be available from:

California Eastern Labs
3260 Jay Street
Santa Clara, California 95054
(408)980-3500

You should be able to substitute many other transceivers, like those made by M/A-COM or Solfan and various types available at flea markets.

REFERENCES

1. Glenn Elmore, N6GN, "Designing A Station For The Microwave Bands, Parts 1-3," *Ham Radio Magazine*, February, June, and October 1988
2. Glen Elmore, N6GN, "Designing A Station For The Microwave Bands, Part 2," *Ham Radio*, June 1988, page 35-37

Invitation to Authors

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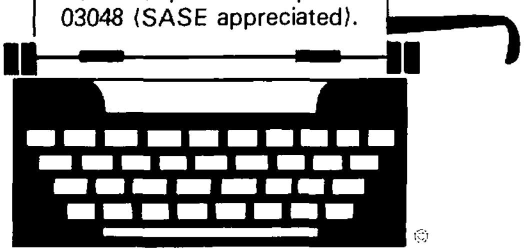


ULTRA LOW POWER FOUR-DIGIT SEQUENCE TOUCH TONE DECODER

By Carl Lyster, WA4ADG, 4412 Damas Road, Knoxville, Tennessee 37921

For some time now Radio Shack has been selling a very useful Touch Tone™ decoder IC for about $12. The all-CMOS IC incorporates the following: on-chip preamp, bandpass filters, voltage regulators, clock generators, and output decoders. All you need to decode a Touch Tone signal is a quartz crystal, a resistor and one capacitor, and 5 volts DC. The performance and reliability of this chip are amazing. By adding a few inexpensive shift registers and comparators, you can build a four-digit sequence decoder for less than $20. **Figure 1** shows the pc board; **Figure 2** is the schematic diagram.

I've built several of these units and used them for applications like repeater autopatch and control link decoders. The response time of the decoder is very fast (specs. = 40 ms), much faster than you can move your finger from one button to another. The power consumption is an unbelievable 6 mA at 5 volts DC.

Hardware description

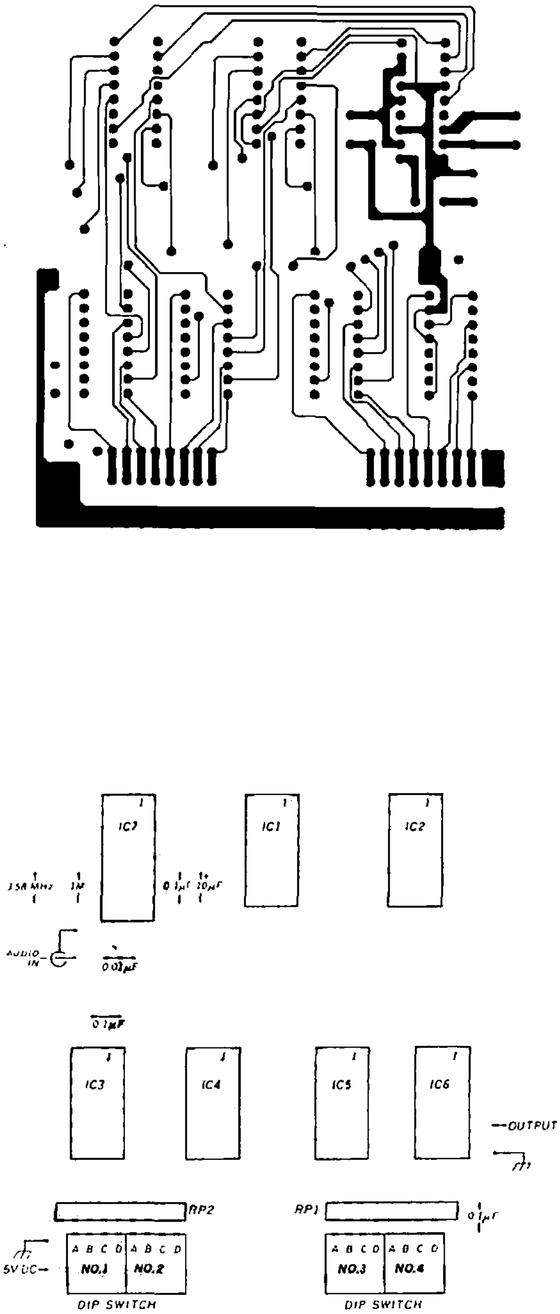
AC-coupled audio enters the decoder on pin 9. To prevent falsing, this level shouldn't exceed 1 volt p-p. Pins 11 and 12 are connected to a "color-burst" 3.58 MHz crystal, also available from Radio Shack. In this circuit, the decoder is configured to detect all 16 standard Touch Tone digits and produce a hexadecimal output corresponding to the digit decoded. Pin 14 is the "valid digit" flag and goes high each time a digit is decoded. The rising edge of each valid digit flag pulse is used to clock the hex data from the decoder into a pair of CD4015 dual four-bit shift registers. The shift registers store the hex data for the last four digits detected. IC1 stores binary bits A and B of the hex code while IC2 stores bits C and D. The corresponding two bits of each shift register position go together to form four, four-bit hex digits. The DCBA data for each digit is sent to a *CD4063 magnitude comparator chip. Each CD4063 com*pares the binary number from the shift register to a binary

TABLE 1

Binary coding chart.

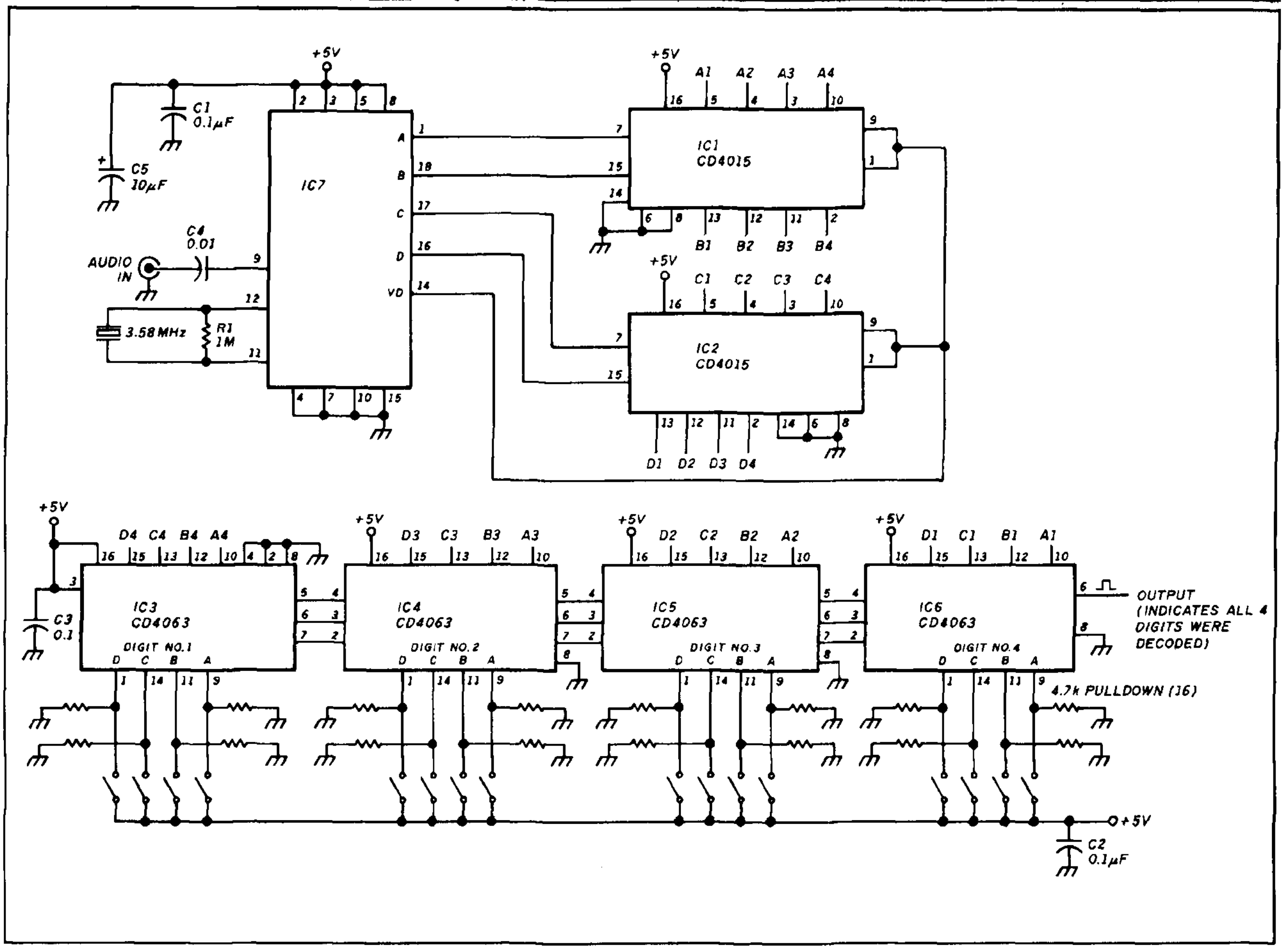
Digit	D (8)	C (4)	B (2)	A (1)
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1
0	1	0	1	0
*	1	0	1	1
#	1	1	0	0
A	1	1	0	1
B	1	1	1	0
C	1	1	1	1
D	0	0	0	0

FIGURE 1



Foil and component sides of pc board.

FIGURE 2



Low power Touch Tone decoder.

PARTS LIST

C1,2,3	0.1μF	ceramic or monolithic bypass
C4	0.01μF	ceramic
C5	10 μF	16-volt electrolitic
IC1,2	CD4015	dual four-bit shift register
IC3,4,5,6	CD4063	or 74HC85 magnitude comparator
IC7	276-1303	Touch Tone™ decoder (Radio Shack)
R1	1 meg	1/4 watt
Crystal	272-1310	color burst 3.58 MHz (Radio Shack)
RP1,2	8 x 47 k	pull-down resistors
SW1,2	275-1301	eight-position dip switch (Radio Shack)

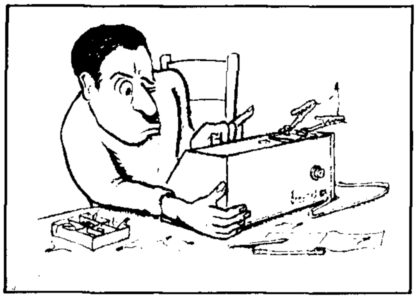
number programmed by a dip switch for each corresponding digit position. When the two numbers are equal the CD4063 generates an "=" flag. As each successive CD4063 receives its correct digit from the shift register matching the programmed digit from the switches, the "=" flag is propagated to the next stage. When all four stages are equal, a high is generated on pin 6 of IC6. This is the final decoded output, and will remain high until another digit is detected and entered into the shift registers. The output can latch an external flip-flop or be connected to whatever logic you desire.

The dip switches I chose contain eight switches per package. This provides two digit positions per package. The DCBA pattern of the switches is equivalent to the more commonly used method of presenting binary data as 8421. Regardless of how you consider the four-bit data, if a dip switch is closed, then that bit is equal to a binary 1, or high. If a switch is open, that bit is a 0, or low. The Touch Tone decoder has a slightly different hexadecimal output than is expected, but you can simply refer to the chart in **Table 1** for the bit pattern of each digit.

After choosing the four-digit sequence you wish to decode, enter the hex data from the chart for the appropriate digit position.

To save space, I used two single in-line 47-k resistor packs for the pull-down resistors on the dip switches. These packs each contain eight 47-k resistors all tied to a common pin. You can replace these packs with individual resistors if you wish. The 47-k value of the pull-down resistors is not critical; however, a lower value for these resistors will result in a higher current draw from the 5-volt supply.

Practically Speaking



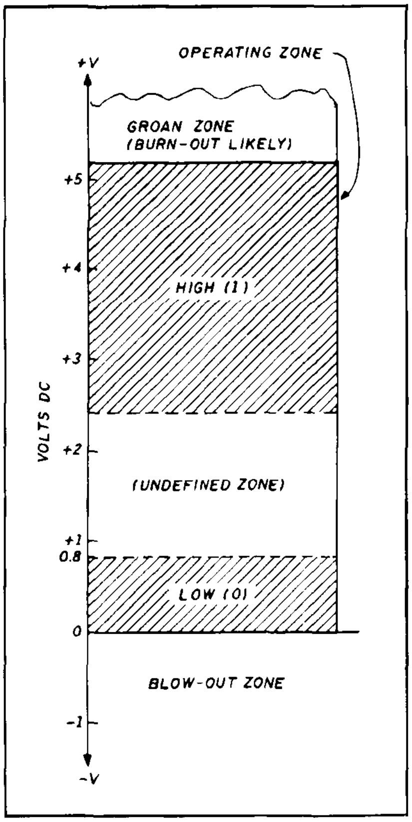
Joseph J. Carr, K4IPV

GETTING TO KNOW THE LOGIC FAMILIES, PART 1: TTL

Of all the IC digital logic families that have been on the market over the past 20 years or so, the *transistor transistor logic* (TTL, or T²L) is probably the most successful. TTL devices require more current than CMOS, but also operate at much faster speeds. Although most TTL devices operate in the 18 to 25-MHz region, special types are available to speeds of 80 MHz. TTL devices are designated by type numbers in the 74xx and 74xxx series (54xx and 54xxx devices are military grade TTL devices). For example, a 7402 is a quad two-input NOR gate and a 5402 is its MIL-SPEC cousin. The principal difference between the 54 series and 74 series is the temperature range. The 74 series is commercial grade and is designed to operate over the range 0 to +70 degrees Celcius; the 54 series operates over −55 to +125 degrees Celcius.

Figure 1 shows the operating regions for logic levels and operating potentials for TTL. The DC power supply must be +4.7 to +5.2 volts, and must be regulated. Although these "official" limits are well publicized, it isn't recommended that you try to operate close to the edges of the range. For example, at +5.2 volts DC the reliability of the devices may be compromised. At the other end of the range, +4.7 volts, some complex function devices may become flaky in their operation — especially in noisy environments. As a result, it's probably best to keep the DC power supply in the +4.9 to +5.1 volts range all of the time. The standard TTL DC power supply is voltage regulated.

FIGURE 1



Voltage ranges for a *valid* "logical 0" or a *valid* "logical 1".

The logic levels for TTL are as follows:

HIGH (logical-1): +2.4 volts to +5 volts
LOW (logical-0): 0 to +0.8 volts

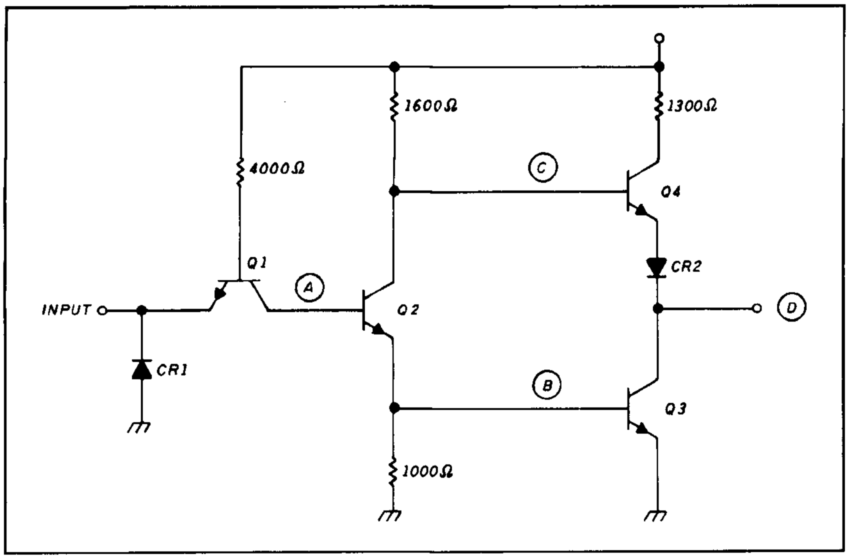
TTL output circuits

The output circuit for a TTL device forms a current sink. That is, the output will accept a current from a TTL input (a current source) and route it to ground. **Figure 2** shows two popular forms of TTL output. In **Figure 2A**, a TTL inverter, you see a regular TTL output circuit consisting of Q3 and Q4. This is the approximate circuit in almost all TTL devices. Transistors Q3 and Q4 are an identical pair, and form a "totem pole" circuit; Q4 is a current regulator and Q3 is the output switch. The series diode CR2 prevents current flow in the wrong direction. When the output is HIGH, transistor Q3 is turned off, so the current from the next stage isn't able to find a path to ground. But when the output is LOW, the transistor is biased hard on (it is in saturation), so the output terminal is grounded.

Figure 2B is an "open collector" TTL output. There's no current regulator in this circuit. That function is taken over by an external *pull-up* resistor (R1). Depending upon the type of open collector TTL device, the V+ voltage can be either +5 volts, or anything up to either +15 or +30 volts. Open collector inverters can be used for interfacing to other logic families, other digital devices, or nondigital output devices (relays, LEDs, lamps). Most open collector devices are hex inverters.

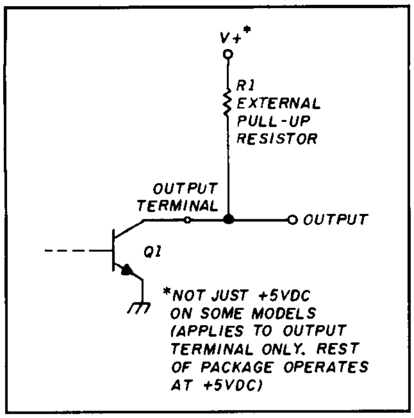
The TTL output is rated according to the number of standard (1.8 mA) TTL inputs it will drive. This number is called the *fan-out* of the device. Thus, a fan-out of ten (the usual number for standard devices) means that it will drive

FIGURE 2A



A regular TTL output circuit consisting of Q3 and Q4. In this "totem-pole" circuit, Q3 is the output switch and Q4 is the current regulator.

FIGURE 2B



An "open collector" TTL output is shown here. Current regulation is provided by an external pull-up resistor.

up to ten standard TTL inputs. The standard TTL input represents a load, or *fan-in*, of one.

Figure 3 shows the relationship between the TTL input and the related TTL output circuit of the previous stage. The input may be a single emitter, as in the case of an inverter, or a multiple emitter. The inputs shown are dual inputs as might be found on a 7400 two-input NAND gate or 7402 two-input NOR gate. *The TTL input is a current source and the TTL output is a current sink.* It's important to keep these distinctions in mind when attempting to interface TTL with non-TTL digital and other circuits.

TTL subfamilies

The overall class of devices called TTL is divided into several subfamilies that are tailored to specified types of applications by differences in operating power, speed, and propagation delay. The ordinary TTL device is called regular TTL. It's typified by power consumptions of about 10 mW per gate and operates to speeds in the 25 to 35-MHz region. Propagation delay is on the order of 10 ns. The other TTL subfamilies include: low power TTL, high power TTL, Schottky TTL, and low power Schottky TTL. The type numbers for these devices are modified as follows:

Series	Typical Type Numbers
Regular TTL	74xx/74xxx
Low power TTL	74Lxx/74Lxxx
High power TTL	74Hxx/74Hxxx
Schottky TTL	74Sxx/74Sxxx
Low power Schottky TTL	74LSxx/74LSxxx

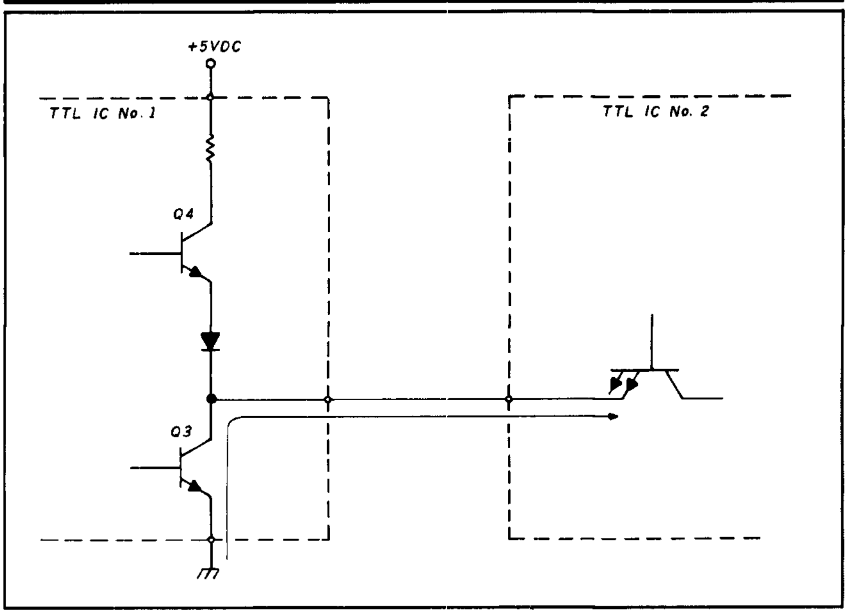
The operating speeds of the various subfamilies are radically different from each other. Typically, the 74xx device operates to 25 to 35 MHz (with some older samples being limited to 18 MHz); 74Lxx operates to 3 MHz; 74Hxx operates to 50 MHz; 74Sxx operates to 125 MHz; and the 74LSxx device operates to 45 MHz.

The fan-out and fan-in requirements also differ between the families:

Series	Output sinks (mA)	Input sources (mA)
74xx	16	1.6
74Lxx	3.6	0.18
74Hxx	20	2.0
74Sxx	20	2.0
74LSxx	8	0.4

Table 1 is a chart showing how many of which kind of inputs each subfamily drives.

FIGURE 3



The relationship between TTL input and related TTL output circuitry is shown here.

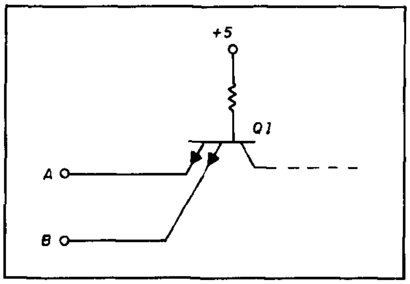
TABLE 1

This chart shows different input and output requirements in the TTL device families.

This output	Will drive this many inputs 74xx	74Lxx	74LSxx	74Hxx	74Sxx
74xx	10	40	20	6	6
74Lxx	2	10	10	1	1
74LS	5	20	10	4	4
74H	12	40	40	10	10
74Sxx	12	40	40	10	10

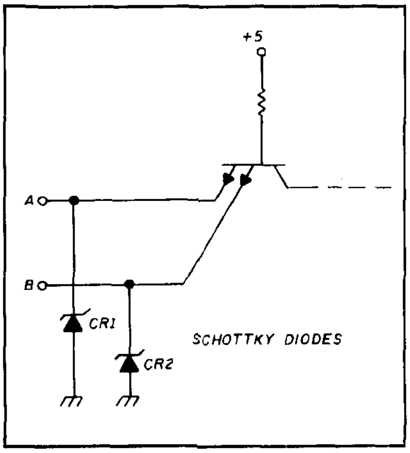
The principal differences between certain of these families can be seen in **Figure 4**. In all three cases a two-input circuit is assumed. The standard "regular" TTL input is shown in **Figure 4A**. The regular input consists of an NPN transistor with two emitter terminals. The Schottky TTL device is similar, except that a pair of Schottky diodes are shunted across the inputs (see **Figure 4B**). Finally, in the LS series TTL a set of four Schottky diodes are used (see **Figure 4C**). In each input, one is in series with the input line and the other is shunted to ground.

FIGURE 4A



A standard TTL input.

FIGURE 4B

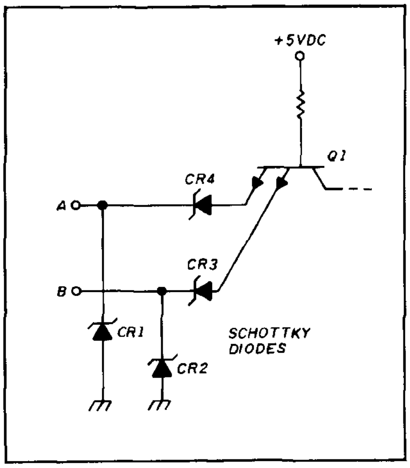


A Schottky TTL device input.

Tri-state logic

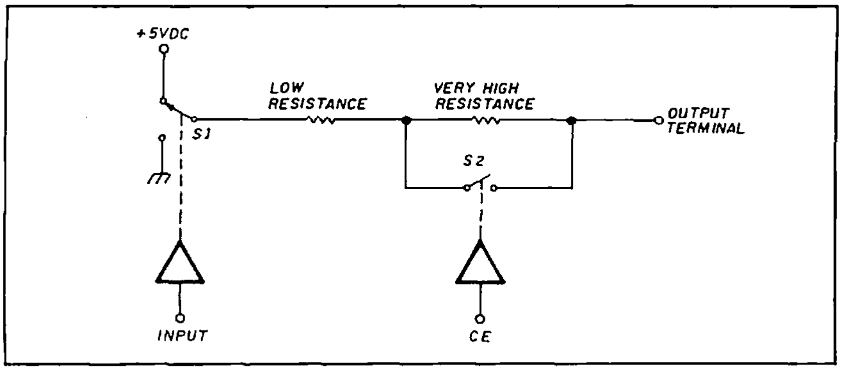
Many TTL and CMOS digital devices are called "tri-state" logic devices. Normal digital devices are two-state types. That is, they are *binary* in nature. This designation means that an output can be only HIGH or LOW — there's no in-between state. But a *tri-state* logic device has a third state in which the output terminal is effectively disconnected from the output circuits. **Figure 5** shows an equivalent circuit for the tri-state device. Switch S1 represents the normal binary operation of any TTL device (in this case an "inverter"). When the input is LOW, the output is HIGH, so switch S1 is connected to the +5 volt source. Alternatively, when the input is HIGH, the output is LOW, so S1 is connected to ground. The tri-state condition is provided by switch S2. When the *chip select* (CS) line is LOW, then switch S2 is closed so the output is connected directly to the inverter output (the S1 pole). But when CS is HIGH, switch S2 is open, so the output terminal is connected to the output

FIGURE 4C



A low power Schottky TTL input with both series and shunt Schottky diodes.

FIGURE 5



Equivalent circuit for a tri-state TTL device.

of the inverter through a very high resistance. This action has the effect of disconnecting the internal circuitry of the device from the output terminal. Tri-state logic devices are mainly used in computer and other digital applications where several devices must share a common bus or line.

Power supply decoupling

There are several general rules for placing power supply bypassing capacitors in TTL circuits. One of two protocols are generally used:

- a single 0.001-μF capacitor at each TTL package, or
- a single 0.01 to 0.1-μF capacitor every second or third device, or every 3 inches — whichever is spaced closest.

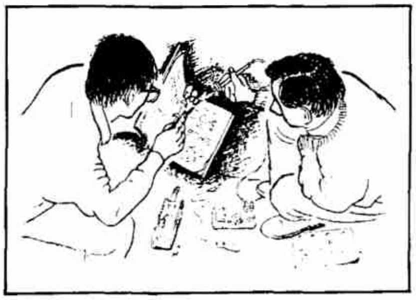
These capacitors are connected between the +5 volts DC terminal of the device and ground. The capacitors should be located close to the device.

On large projects it's advisable to place a 50 to 200-μF capacitor at the power supply connection for the printed wiring board, and 4.7 μF every 10 to 12 inches along the +5 volt bus.

If you build a really large project, one that draws 4 to 10 A from the +5 volt line, you might want to consider one of two power supply schemes. In the first, you use a voltage regulator with a *sense* line. That type of DC power supply has a reference voltage sensing line connected at the point where you want the voltage to be +5 volts. The DC resistance of the power supply bus causes a voltage drop that can hurt the operation of the circuits. The second uses distributed regulation. In this scheme, the main DC power bus is +8 volts. Each printed wiring board, or several sections of the same board, has its own three-terminal IC voltage regulator. The S-100 microcomputer (the original microcomputer) used this system. Each S-100 plug-in card had one to five 7805, LM-340T-05, LM-340K-05, or LM-309 voltage regulators.

Conclusion

Transistor transistor logic devices are inexpensive and are, for the most part, well behaved in practical circuits. You should be able to use them easily in both published construction projects or custom-designed projects of your own.



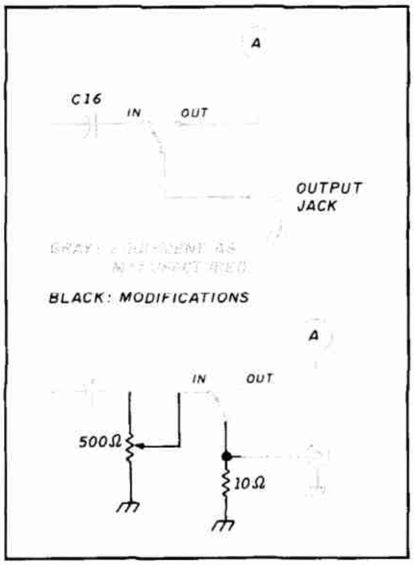
Optimizing The QF-1A Audio Filter

These small additions to the Autek QF-1A audio filter won't take an entire weekend, but you may find you want to spend some time playing with the settings (of the new controls and the existing ones) afterwards.

Setting up the rig

With the unmodified QF-1A filter in circuit but switched to OFF (BYPASS), experiment with the RF gain control of your rig while listening to a weak (just above the noise) SSB signal. Concentrate on finding the setting that gives you the best signal-to-noise ratio and intelligibility. This will *not* be the setting that gives the *loudest* signal. You may be surprised to find how far back you have to turn the RF gain — especially if you're an old-timer brought up on the "full RF gain for fone, retarded for CW" rule popular in the old days of AM and diode detectors. The rule for SSB and product detectors is, "If you can hear the background noise in the absence of a signal, a receivable signal will be audible above it." This applies especially if you have a lot of local manmade noise.

FIGURE 1



Change to output.

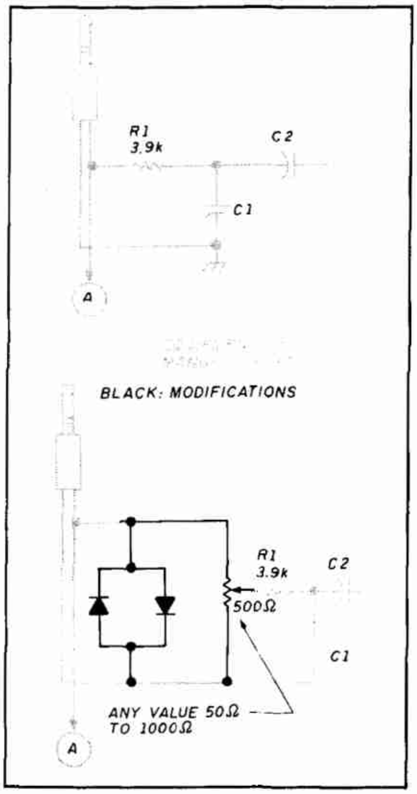
After you've found the best place for the RF gain, adjust the AF gain to a comfortable listening level. (If you're using headphones, and the comfortable audio level is near minimum AF control setting, you might consider putting a series resistor in the headset plug.)

Now switch on the QF-1A with the function switch on LOWPASS and all the other controls fully counterclockwise. If the audio is louder than it was before, you need the modification shown in **Figure 1**. (If it's not, you may still need it when you increase the filter gain by turning the selectivity control up.)

The next test is done more easily on CW. With the filter switched OFF find a CW signal, or (preferably) a constant audio tone from a calibrator or WWV, and select a comfortable audio level. Switch on the filter, put the QF-1A function switch at PEAK, the selectivity control at half scale or more, and swing the frequency control above and below the peak frequency. Note the approximate width of the peak. There's no need to be precise; just get the feel of it.

Reduce the setting of the AF gain on the rig and swing the frequency control again. If it's sharper than it was before, the output from the rig was overloading the filter and you need the modification shown in **Figure 2**. The back-to-back silicon diodes in **Figure 2** are included mainly to protect your ears from the sudden arrival of a huge signal or the Woodpecker.

FIGURE 2



Change to input

The modifications

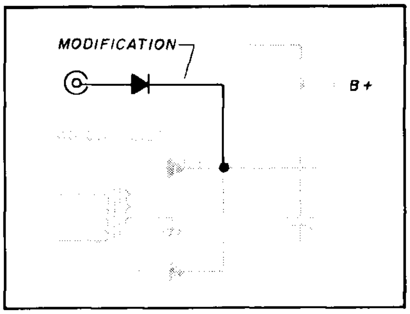
It's convenient to run the QF-1A from one of the 12-volt accessory sockets of the rig if the supply line is 12 volts positive (it only takes a fraction of a watt). **Figure 3** shows a suitable point to make the connection. A silicon diode in series protects the filter if it's plugged into a 12-volt negative line accidentally. There's plenty of room on the back wall of the filter enclosure for the two new potentiometers and an RCA-type socket. Physically, the pots can be as small as you like and the value isn't critical — somewhere between 50 and 500 ohms is ideal.

The 10-ohm resistor in **Figure 1** presents a reasonably low impedance load to the filter, even if you use high impedance headphones.

Adjusting the pots

After you've completed the modifications, turn both pots to maximum. The output should sound just as it did before. Make the CW test again. But after switching the filter on, reduce the input pot until the signal no longer saturates the filter. Then adjust the output pot until the audio level is about the same, whether the filter is ON or OFF.

FIGURE 3



+12 volts dc from rig. Diode is to protect QF1-A against accidental connection to −12 volt supply.

Adjusting the filter

You may prefer to make adjustments based on your own methods. For what it's worth, this is what I do on SSB. (I find the rig itself copes pretty well most of the time on CW.)

I set the function switch on LOW-PASS and the selectivity and frequency controls fully counterclockwise. Then, with a signal that has some noise on it I turn the frequency control until the high frequency components of the voice just begin to be attenuated. This usually results in a vast reduction of the noise. I leave the controls at this setting most of the time. I may, however, turn the frequency control a bit to the right on CW, "roofing" the noise somewhere just above the CW tone.

It often helps to adjust the AUX NOTCH control to about 10 o'clock on a particularly noisy SSB signal, leaving the selectivity control at *minimum* to give a broad notch. That's about it. The QF-1A is an excellent filter just the way it is, but adding these two controls lets you customize it to give optimum performance on your rig.

Bob Eldridge, VE7BS

Using The ICOM IC-32AT As A Crossband "Mini-Repeater"

Here's a simple modification that lets you use your IC-32AT as a crossband repeater. All you need to do as far as the hardware is concerned is clip diode D912 on the logic unit. Once you've done this and reassembled the radio, use the keypad to place the radio into crossband repeat mode:

- Push and hold the FUNCTION switch on the side of the radio.
- Push the [C] key.
- Push the [6] key.
- Push the [D] key.
- Release the FUNCTION switch.

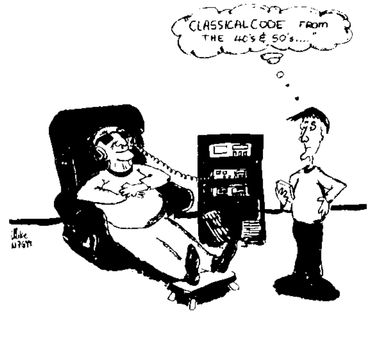
To cancel the repeater function, enter the following on the keypad:

- Push and hold the FUNCTION switch on the side of the radio.
- Push the [D] key.
- Push the [C] key.
- Release the FUNCTION switch.

When the radio is in repeater mode, you'll note that it scans between the VHF and UHF frequencies last programmed into the VFOs. The radio will continue to scan between these two frequencies until a signal breaks the squelch or you stop the scan manually. When the scanning has stopped, the transmit frequency will be displayed until the incoming signal terminates. If the incoming signal was in the VHF/VFO, it will be retransmitted automatically on the UHF/VFO, and vice versa.

I think you'll find this feature useful if you're ever in an emergency situation, or communicating with someone who has VHF or UHF capabilities only.

Russell Dudley, KW5O



THE FIVE-BAND JUNKBOX TRANSMITTER

Short on cash but long on spare parts? This is the radio for you!

By Charlie Tiemeyer, W3RMD, RD 2, Box 427-C, Chestertown, Maryland 21620

Many Amateurs wonder how they can pursue their hobby *inexpensively*. Some are fortunate enough to have a sizable junkbox or an Elmer who's happy to contribute parts. Of course, there are probably plenty of old TV or radio sets around which contain the parts we need.

Transmitter

Figure 1 shows the schematic of my junkbox rig. The oscillator is a 6AQ5 tube and the final amplifier a 6DQ6. I chose these tubes because I have quite a few on hand. Any tube that renders reasonable output will work. I suggest that you select a final amplifier tube that can handle the output voltage of the power transformer you intend to use. My transformer is a 730-volt center-tapped unit I built about 35 years ago for a homebrew AM modulator. You may have one that delivers higher voltage which will let you use a 6146 or 807 in the final, allowing more power output.

Construction

All components were mounted and installed on an aluminum chassis, 13″ × 7″ × 2″. I suggest you mount the components logically and keep all leads as short as possible when soldering. I salvaged my tunable oscillator coil and the input and output variable capacitors of the pi-network final from a defunct Globe Chief transmitter. The tank coil was resurrected from a cannibalized Drake 2-NT transmitter, but any final coil from an old Globe Chief, DX-40, or DX-60 will suffice. If you can't find these particular parts, refer to **Tables 1** and **2** for coil data for both the tunable oscillator and the final tank circuit.

I prefer to operate 80 and 40 meters. If you want other bands, you'll need a switching arrangement to short circuit the unnecessary parts of the coils. I have used the 40-meter taps successfully to work 30 meters with 5-MHz crystals. Both oscillator and final tank coils are wound on 1″ diameter forms (see **Tables 1** and **2**).

Although I didn't try it, I think you could use 12 meters with either the 15 or 10-meter band coil positions and the appropriate crystals. You'll need to experiment. I also think it's possible to use *one* wire size instead of the three indicated. Because I've listed a maximum of 35 turns of wire, you can use one longer 1″ diameter coil form with taps at the appropriate bands. You'll need all 35 turns for 80 meters. For 40 meters, the tap would be up twelve turns. Twenty meters would be up from this tap at thirteen turns, 15 meters at four turns, 10 meters up at one turn, and 15 and 10 meters would be space wound.

The same arrangement used with the oscilator coil(s) applies for 12 meters on the final tank coil(s). Use a 1″ coil form with 30 turns for 80 meters. For 40 meters, the tap would be up 13 turns. Twenty meters would be up from this tap at 11 turns, 15 meters up 2 turns, and 10 meters up 1 turn and space wound.

Because I operate this rig on 80 and 40 meters only, I use copper alligator clips to short wanted turns on both the

TABLE 1

Oscillator coil(s).

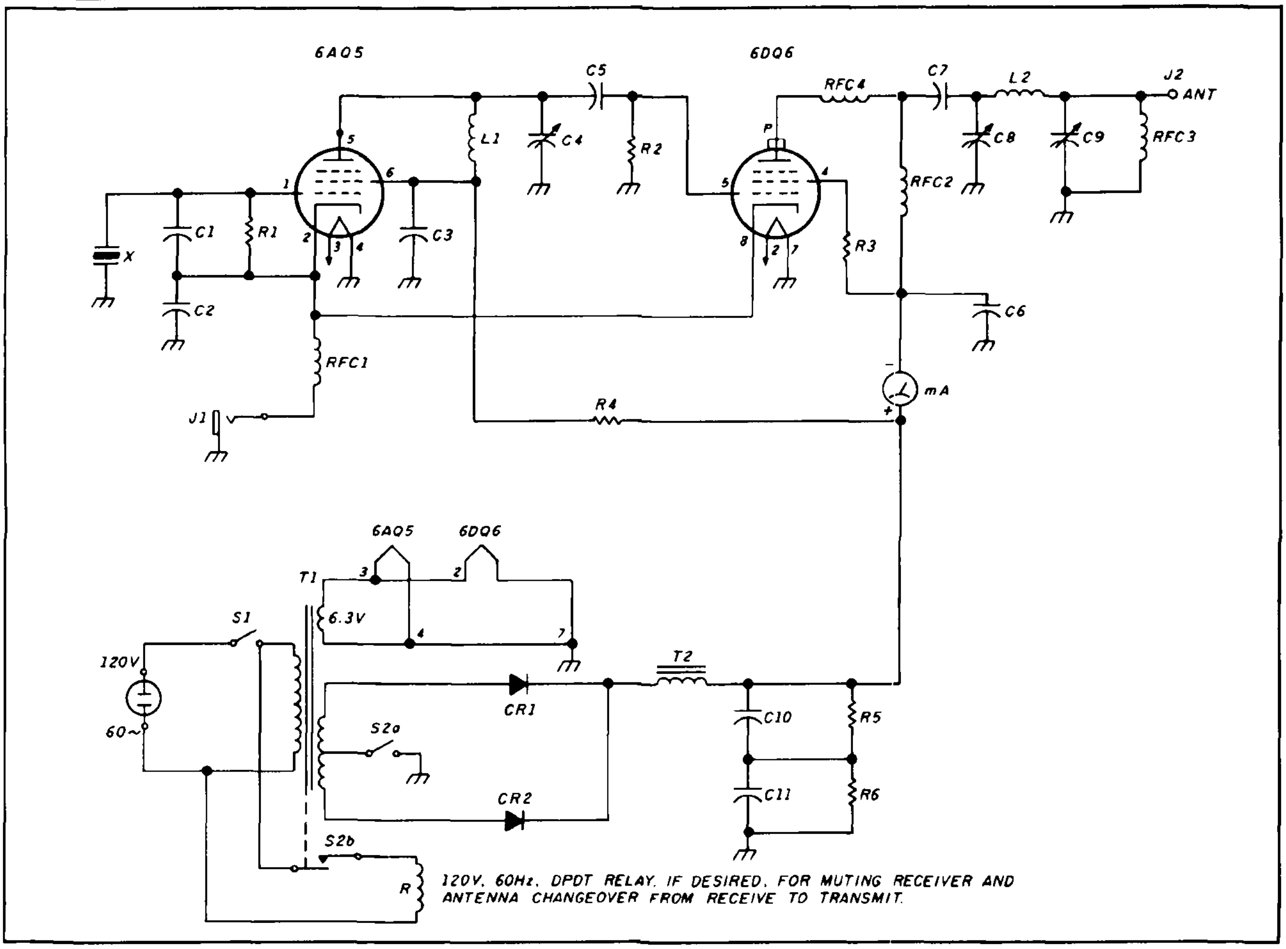
80 meters, 35 turns no. 22 enamel wire close wound
40 meters, 23 turns no. 22 enamel wire close wound
20 meters, 10 turns no. 22 enamel wire close wound
15 meters, 6 turns no. 18 enamel wire space wound by wire diameter
10 meters, 5 turns no. 16 enamel wire space wound by wire diameter

TABLE 2

Final (tank) coil(s).

80 meters, 30 turns no. 14, 16, or 18 enamel wire close wound
40 meters, 17 turns no. 14, 16, or 18 enamel wire close wound
20 meters, 6 turns no. 14, 16, or 18 enamel wire space wound by wire diameter
15 meters, 4 turns no. 14, 16, or 18 enamel wire double spaced by wire diameter
10 meters, 3 turns no. 14, 16, or 18 enamel wire double spaced by wire diameter

FIGURE 1



Schematic of the five-band junkbox transmitter.

PARTS LIST

C1	22-pF or 0 to 30-pF trimmer capacitor
C2,C5	100-pF disc ceramic capacitors or mica
C3	0.01-μF 1 kV± disc ceramic or mica capacitors
C4	100-pF variable capacitor, broadcast type okay
C6,C7	0.001 to 0.005-μF 1 kV± disc ceramic or mica capacitors
C8	350 to 450-pF variable tuning capacitor, broadcast type okay
C9	1200-pF variable tuning capacitor (usually 3 gang ±400 pF, each gang in parallel)
C10,C11	80 or 100-μF 450-volt electrolytic capacitors in series
R1	47-k, 1/2 or 1-watt carbon resistor
R2	27-k, 1/2 or 1-watt carbon resistor
R3	4-k, 10-watt wire-wound resistor
R4	1.5-k, 10-watt wire-wound resistor (may not need if 300 volts not exceeded)
P5,R6	330-k, 1-watt carbon equalizing resistors (470 k okay)
X	Any 80 or 40-meter crystal
RFC1,RFC2, RFC3	2.5-mH (1 mH okay) 125 to 150-mA RF chokes
PFC4	7 turns no. 20 wire space wound on 47-ohm, 1-watt carbon resistor
T1	See text (any voltage from about 350 to 450 each side of center)
T2	Any choke from 5 to 10 H, 100 to 200 mA
CR1,CR2	1000-PIV, 400-mA or more silicon diodes
S1	SPST toggle switch
S2	DPDT toggle switch (if relay is used, otherwise same as S1)
J1	Open or closed-circuit phone jack for key
J2	Coaxial receptacle, no. SO-239
MA	0 to 200-mA milliammeter for loading PA
R	Relay for muting receiver and antenna changeover (optional)

oscillator and final tank coils. If you can obtain these coils from old discarded transmitters, you'll find that the proper tap points for each band are indented on the forms or may still have leads extending from them. If they aren't available, you'll need to follow the steps for winding your own.

Recommended voltages and currents

My rig has voltages and currents based on the power transformer I'm using. These are shown in **Table 3**. I don't know the transformer's current rating, but I think that any reasonable unit capable of at least 150 mA (preferably around 200 mA) would be adequate. If you have a transformer capable of 400 or 500-volts output, you might need to use a different power amplifier tube. You'll also need appropriate screen-dropping resistors for the final tube and for the plate and screen of the oscillator tube to avoid overload.

This rig uses choke input for better regulation, but you can use capacitor input and get more output voltage. My transformer is rated around 365-0-365 volts at choke input and resolves to 365 volts × 0.90, or approximately 328 volts. For capacitor input, 365 volts × 1.2 = 438 volts output; for no load, 365 volts × 1.4 = 511 volts. However, I *assume* my transformer is 365-0-365 volts; hence I arrived at the data in **Table 3** taken on both 40 and 80 meters.

Tuneup

Tuning up is simple. Put all three variable capacitors at *maximum capacitance* (plates fully meshed). Don't forget to use a dummy load to tune up before attaching an antenna. While listening to your receiver around your crystal frequency, close switch S2, depress the key, and quickly tune C4 for the loudest signal. Then tune C8 for minimum dip in plate current: this should be less than 100 mA. Increase C9 a little at a time, redipping C8 until you've loaded between 100 and 150 mA after each try. Actually, 125 mA is best. Now you're ready to operate.

TABLE 3

No load voltages, 470 volts choke input.
305 volts at 100 mA = 32 watts input, 235 volts to 6AQ5, 200 volts to 6DQ6 screen
300 volts at 125 mA = 38 watts input, 230 volts to 6AQ5, 210 volts to 6DQ6 screen
295 volts at 150 mA = 44 watts input, 220 volts to 6AQ5, 230 volts to 6DQ6 screen

Some closing thoughts

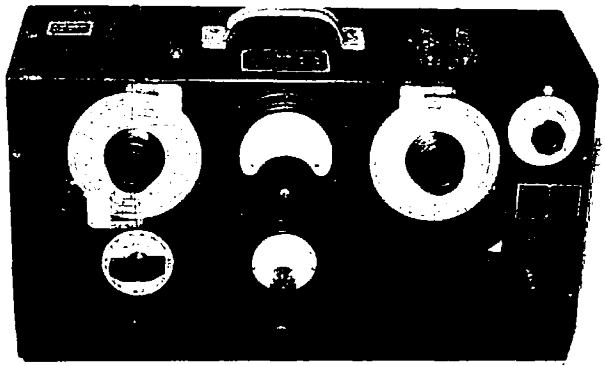
There you have it. I'm still having fun with this little rig and getting excellent results and reports. I haven't tried my old Heathkit VF-1 VFO with it yet, but feel it would give me more versatility — assuming it works okay in place of my crystals. I have a "rock pile" accumulated through many years in Amateur radio; however, I prefer crystal control for the obvious stability.

I think you'll not only enjoy building and experimenting with this rig, but will have many enjoyable hours on the air. hr

Q METERS

By Keats A. Pullen, Jr., W3QOM, 2807 Jerusalem Road, Kingsville, Maryland 21087

PHOTO A



Front panel view of a Q meter.

Keep your eyes open at the next hamfest you attend. You may see a Q meter at a good price (under $50). Once you know how to use it, you'll find it's one of the most useful test instruments to own.

However, there's a problem with Q meters today. Units like the Boonton type 160-A model 1 are full of antiquated tubes. The 160-A uses tubes with 2.5-volt filaments (types 45 and 2A6, a dual diode triode with a grid lead on the top). The unit I picked up didn't respond to Q measurements, so I decided to replace these tubes with more modern 6-volt types — like the 6Y6GT or 6AR6 in place of the 45, or a 6J6 in place of the 2A6. Get spares, and test them to be sure they work!

How does it work?

Q is measured using a fundamental characteristic of series LC circuits. At resonance, the magnitude of the voltage appearing across either reactance is equal to the voltage induced in the circuit, multiplied by the "circuit" Q. Through careful test instrument design, the circuit Q is essentially the same as the Q of the component under test.

A brief description of the type 160-A Q meter is in order. The meter consists of two sections, an oscillator and a voltmeter. The oscillator uses a type 45 triode to provide the required RF current to the exciting circuit, which consists of a resistive ribbon with a value of 40 milliohms. The coil to be measured is connected from the ungrounded end of this resistance to the stator terminal of a built-in variable capacitor to provide the series test circuit. This resistance must have enough current running through it to give about a 10-mV drop at the test frequency. The amount of RF current in the exciting resistor must be of sufficient magnitude that the resonant current due to the Q multiplication won't make a significant change in the resistor current.

I selected the 6J6 tube, a dual diode triode unit, for its extremely high "mu" or amplification factor. A 12BZ7 triode has similar properties and adequate gm, but the 6J6 can be made to work. Whatever tube you choose, it's used in a circuit called an "infinite impedance" detector circuit; it's biased nearly at cutoff, and the positive swing of the signal causes the tube to draw current. The voltage change across the cathode resistance is measured by a simple DC voltmeter.

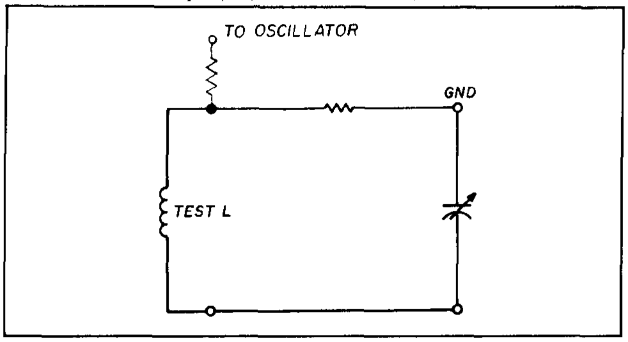
Because of this, there's a frequency-range changing switch and a tuning circuit on the left side of the instrument which selects the desired operating frequency (see Photo A). The amplitude of the applied current to the test circuit is set by the smaller meter and the two knobs to its right. The left knob is the coarse adjustment; the right is the fine.

The meter that indicates the value of Q measures the voltage generated across the cathode resistor of the infinite impedance detector. The detector senses the RF voltage across the tuned circuit, consisting of the coil and the variable capacitor which is calibrated from 30 to 450 pF. This capacitor is just to the right of the Q measuring meter. The small knob below the meter is used for adjusting the zero setting of the meter. This setting may be somewhat sensitive to the level of current in the tuned circuit, as the knobs that control the RF current act by varying the output supply voltage to the oscillator tube. The zero set should be done after the signal amplitude has been set in the current meter.

The layout for the coil connections is indicated by the binding posts on the top of the instrument (see Figure 1). There's one terminal for ground, one for the injection resistance, and two for the ungrounded end of the capacitor — which also connects to the grid of the detector tube. I'll describe the various ways to use these connections later.

The 45/6Y6GT/6AR6 tube operates as a power oscillator and provides up to 1 A of RF current to the measurement circuit. This current level must be much higher than the circulating current that flows in the test circuit at the highest possible Q factor. This current flows through a thermocouple, and perhaps some additional resistance, in addition to the injection resistance that excites the tuned circuit under test. The thermocouple provides metering current to a panel meter that indicates the magnitude of current flow, thereby giving a multiplicative factor for the Q reading. It's very

FIGURE 1



Binding post placement on the instrument.

important that the thermocouple current be limited to a maximum indicated value of 1 on the multiplier meter; too much current can easily burn out the thermocouple. The thermocouple is very delicate and can't tolerate any overshoot.

The metering circuit uses only the triode section of the 2A6. The diodes would load the circuit and keep it from operating properly. There's a small resistance in series with the filament in this arrangement to minimize the zero-bias grid current and make the unit work more effectively. Using the infinite impedance detector configuration further reduces the loading. In addition, the relation between the plate current and the bias is very nonlinear. This lets it suppress the negative half cycle of the applied signal, and gives an output current that rises rapidly with the increase in applied signal.

Don't be surprised if you haven't heard of the infinite impedance detector. I learned of its existance before World War II, and haven't seen any use of this unique circuit since — except for this Q meter application. The advantage of this detector is that it doesn't load a circuit that it's coupled to, and lets you measure the output voltage of the tuned circuit without degrading it, as would a diode. The "output" obtained with this detector is taken across a cathode resistor, and the circuit behaves like a cathode or an emitter follower. I'll give more information about the process for setting the bias current level on this tube later.

There are several different definitions of Q, but as long as the measured Q exceeds 10, the definitions are, for practical purposes, more or less equivalent. A good discussion of Q appears on page 110 of the September 1988 issue of *Ham Radio*.[1] It's usually defined as the ratio of the reactance of the capacitor, divided by the effective internal resistance of the overall tuned circuit. (This is usually greater than the DC resistance.) The best definition involves the ratio of the stored energy in the coil or the capacitor per cycle, divided by the dissipated energy per cycle. This may occur at a slightly different frequency, but gives essentially the same value of Q.

Possibly useful changes

If the unit is working reliably with the existing tubes (or tubes you bought at a hamfest) don't change anything, but do acquire tubes that you can use to modernize your meter at a later date. If the Q voltmeter doesn't seem to function reliably on RF (mine didn't), you may find my changes useful. Incidentally, the "AC hum" technique used to make a rough test of the detector circuit may not be a valid test for the unit's high frequency operation. The detector requires a 5-volt signal for full-scale deflection, but its operation at 60 Hz indicates only that the circuit should be okay. Check to be sure that the lower "calibration" meter deflects upscale as the left knob to the right of the meter is turned slowly clockwise. When testing, **always** be sure to turn these knobs counterclockwise before turning the instrument on. Protect that thermocouple!

A need to change to 6-volt tubes may be indicated if either tube is inoperative and you can't find spares. (You may not be able to test the original tubes with present-day tube testers.) If the lower meter fails to deflect on one or two ranges only, the problem is certainly an oscillator tube. If it doesn't deflect on any range, it could be either the tube or the thermocouple. Be careful: the thermocouple is inside the oscillator box, and is hard to get to. You may be able to get a hint of what's causing the problem by disconnecting the leads on the lower meter and measuring the resistance through the leads. (That will indicate continuity in the thermocouple itself.) If the thermocouple is burned out, there's a good possibility that the metering circuit to the meter is also open.

I used a 6-volt, 2-A transformer like the one sold by Radio Shack for my new filament transformer. A center tap isn't necessary. One end of the filament winding connects to ground and the other goes in place of the ungrounded end of the 2.5-volt winding which is, of course, disconnected. These are on the tie-point strip near the variable capacitor.

You must take apart the oscillator assembly to change the tube socket from four pin to octal — preferably a low loss socket. Move the heater leads from the larger pins on the four-prong socket to pins 2 and 7 on the octal socket (6Y6GT only). Ground the cathode, pin 8. Attach the grid connection to pin 5, the plate to pin 3.

Pin 4 is now the screen grid lead. It must be bypassed to cathode at the socket, and brought out of the oscillator shield. (To minimize leakage, mount a small resistance just inside the shield at the point of exit. About 100 ohms should work.) Bypass the lead at the point of exit to keep RF from leaking out. A 0.01-μF ceramic should be fine. You can back it up with a larger capacitor if you wish. This lead shouldn't be connected directly to the plate supply, but should have a resistor in series to the supply. I brought it out to a dropping resistance that connects to the center terminal of the large, high wattage potentiometer found just to the right of the lower meter. Start with a resistance of about 25,000 ohms and decrease it until the multiplier meter reads unity, with the potentiometers set near maximum clockwise setting. Adjust both the plate and screen voltages by these resistances.

I replaced the 2A6 tube with a 6J6 tube. My old (1973) ARRL handbook lists the 2A6 and gives the basing connections, but it doesn't indicate the characteristics otherwise. My (older) RCA tube handbook implies that the tube is essentially similar to the 6SQ7 (or 6Q7), and that it requires very little negative bias between cathode and grid to stop current flow. The 6J6 requires significantly more bias, and gave me some problems initially. Two zener diodes and a few spare resistors straightened things out. A 6T8A is an another possibility.

I put my 6J6 tube on a small metal "outrigger" that I could attach to the frame of the main variable capacitor.

A 100-meg resistor runs across the stator of the capacitor to its frame. I left it in the circuit connected to the grid. I put a capacitor from the stator to the 6J6 grids. This blocks the detector's 60-Hz sensitivity. I also put a small (51 ohm) resistor between the two grids to minimize the possibility of parasitics in the 6J6.

To limit the plate voltage on the 6J6 to 100 volts, I added a gaseous voltage regulator (OA2). This improved the stability of the detector significantly when I corrected other problems. Stabilizing the plate voltage on the 6J6 stabilizes its operating point, because of the cathode degeneration in the infinite impedance detector.

I had to bias the cathode of the 6J6 to a point that would place it in the nonlinear operating region. This required about 5 volts of forward bias on the cathode. The best way to get this was by using a zener diode. The bias point varies from tube to tube, so check the bias point of the tube you choose. I made a little voltage divider (see **Figure 2**) to vary the cathode potential, and adjusted the forward bias until there was only about 1/10-volt bias across the cathode resistor — about 10,000 ohms. Then I found a zener diode with that forward drop at about 5 to 10 mA current, and inserted a resistance to the 100 volts from the OA2 to draw that much current (see **Figure 3**).

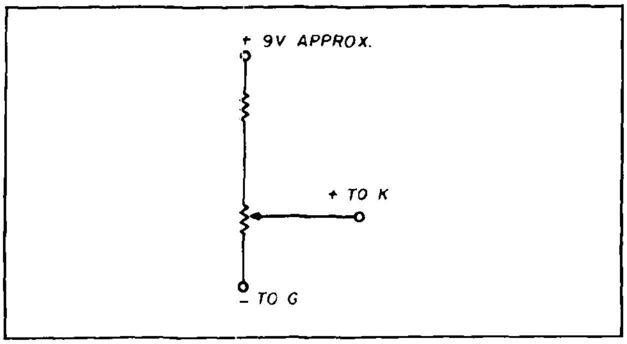
There are a number of high wattage power resistors (at least 5 watts) behind the rectifier tube on the lower subchassis. The lower ends of some of these resistors are connected together, and are also connected to ground. The smallest of these is the cathode resistor for the 2A6. I disconnected the cathode resistor's lower connection from its neighbor and installed the zener diode between the two, so the cathode resistor had its return end about 5 volts above ground. As I mentioned before, I attached a resistance from the bottom lead of the cathode resistor to the stabilized 100 volts. To assure proper operation, the zener diode current should be about 10 mA, and the quiescent voltage across the cathode return resistor shouldn't exceed 0.1 volts.

I returned the cathode lead on the 6J6 to the cathode lead on the bottom of the 2A6 socket, pin 5. There are several bypasses on this point and also continuity to the top of the smaller of the power resistors. I bypassed this lead to ground on the 6J6 socket, and bypassed the plates to ground. (The plates return to the 100 volts from the regulator; refer to **Figure 3**).

I installed a 2-ohm power resistor in series with the ungrounded end of the 6J6's heater lead to reduce the heater voltage and the emission energy of the electrons leaving the cathode. This helps keep the input impedance of the grid circuit very high. Boonton had such a resistance in the 2A6 filament lead.

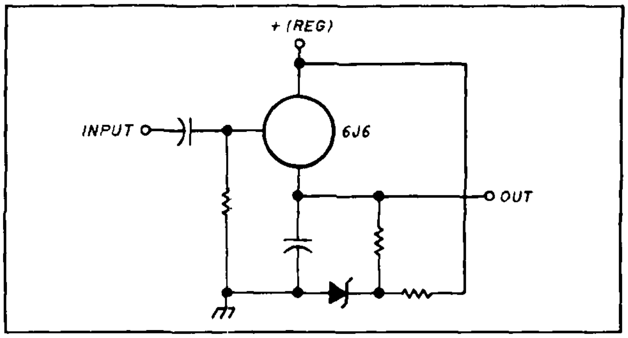
At this point, everything was working well, but the zero point on the Q measuring meter was changing with the power setting. It turned out that the voltage regulation of the high voltage supply was changing with oscillator loading. Once again, I solved my problem with a zener diode. For best all-around operation, two zener diodes here may be better than one. One diode connects from ground to the fourth tie-point from the filament ground. (The resistance between the two points should be taken out.) The second diode (perhaps about 7 volts) goes from ground to the "high" end of the Q meter adjustment potentiometer. With both ends stabilized, the reading is no longer a function of power level in the oscillator. The problem was one of DC shift all along!

FIGURE 2



Simple bias divider.

FIGURE 3



Bias setup for the 6J6.

Now, test your unit with a coil from your junkbox. It should work with no problems.

Using the Q meter

The overall scope of these instruments is really quite remarkable. I'll touch on the more common applications. Q meters can be used to measure the inductance of a coil, what its Q may be at a desired operating frequency, and what capacitance it should be used with. For instance, I may want to know if I can use a certain coil, or I may want to make a coil for operation at a selected frequency. I place the coil between the low and high terminals and start searching — first in the neighborhood of the desired operating frequency. Then I set the selected frequency with the range and tuning controls on the left side of the instrument, and tune the right-hand capacitor over its full range. I may get a peak. If so, I read the capacitance and see if it's close to what I want. If I don't get a peak, I have to start searching. If I think the inductance may be too small, I move the range switch to a higher frequency range and repeat the process, readjusting the power setting as necessary to protect the thermocouple. Once I get a peak, I can calculate the inductance and read the Q at that frequency.

Perhaps I want to know the operating frequency of a coil with a given capacitance. The connections are the same; I set the capacitance and vary the frequency of the oscillator until I find it. Then I can go to a desired frequency and measure its Q.

There are reasons why I may not wish to measure a coil at its chosen operating frequency. One of the most important ones is that the minimum capacitance on the tuning capacitor is only about 30 pF and the maximum is approximately 450 pF. My design may tell me I need over 1000 pF, or less than 10, for example. I then measure at a frequency that fits the range of the instrument.

A Q meter can also be used to measure inductance. Simply find some set frequencies at which to make the measurements and make a calibration for the capacitor dial to read inductances. The calibration is based on an assumption of an inductance that is a multiple of 10 when the capacitor is set at 450 pF. Set the frequency at one frequency first and then move to another, until you find a resonance on the meter. Read the capacitance and select the correct inductance.

You aren't limited to a top capacitance of 500 pF. You can parallel a silver-mica capacitor across the internal capacitor and continue as before. The equations you need are:

$$L = 1/((2\times\pi\times f)\times C) = 1/(39.5\times C\times f^2) \qquad \textbf{(1)}$$

where (f^2) is f squared and C is the total capacitance,
f is frequency in cycles per second,
L is inductance in henries,
C is capacitance in farads.
Note that if L is in microhenries and C in microfarads, then f is in megacycles (MHz).

$$XL = 6.3\times f\times L \qquad \textbf{(2)}$$

$$Reff = 6.3\times f\times L/Q = XL/Q \qquad \textbf{(3)}$$

$$Ztuned = 6.3\times f\times L\times Q = Q\times XL \qquad \textbf{(4)}$$

These numbers are all important, but you can learn more.

Suppose you want to test a circuit using an untuned coupling link to drive the tuned circuit. In this case, you'd connect the untuned link from the low terminal to ground, and the tuned coil from the high terminal to ground. You can use this combination to test the combination circuit; it will give a test of effective Q (here the product of coupling and Q). Test a double-tuned circuit in a similar fashion. Use a fixed capacitor from the "high" end of the injection tuned circuit, and place the second coil from ground to high on the tuning capacitor. Adjust the tuning so both coils peak, vary your coupling as needed, and observe the behavior of the coupled circuit as the frequency changes.

Why do you need the value of a tuned impedance? Amplifier stability is a function of voltage gain, not current gain. Beta and triode mu can't be used to find the voltage gain — only transconductance can. The gain Kv is:

$$Kv = gm\times RL \qquad \textbf{(5)}$$

where RL is the tuned impedance.

Voltage gain *must* be limited to assure stable operation; values under 10 are usually desirable.

You say you don't normally know gm or transconductance for solid-state devices? That's not a problem. It's approximately 39xIc with a bipolar transistor, where Ic is the collector current. (q/kT has a value of 39!) The transconductance has similar form with FETs and electron tubes, but needs an efficiency factor which I call kappa, that must be multiplied by 39 and the output current. This is particularly important with transmitters, where large blocks of power must be handled.

Note that:

q (charge on an electron) = 1.6×10^{-19} coulombs
k (Boltzman constant) = 1.38×10^{-23} joules/Kelvin
T (absolute temperature) = 296°

You can measure kappa easily for any operating conditions you desire. Select an output current that is 2/3 of the desired operating current, and one that is 4/3 of the present operating current. Read the change in input voltage required to switch the output current from one value to the other with a voltmeter, and divide that voltage change into 0.018, which is kT/q times the natural logarithm of 2. The resulting value of kappa varies slowly, so you're in business! Multiply this quotient by the value of output current in amperes and by 39 to get the device transconductance at that value of current. The product of this number and the load impedance gives the voltage gain. Incidentally, if you multiply the reciprocal of kappa by 3 you'll have a measure of the maximum output supply voltage that can be applied to the device in question. There are other ramifications of this, too detailed to examine here.

Once you get your Q meter running, you can have all kinds of fun building RF circuits, amplifiers, and filters. Have a good time! hr

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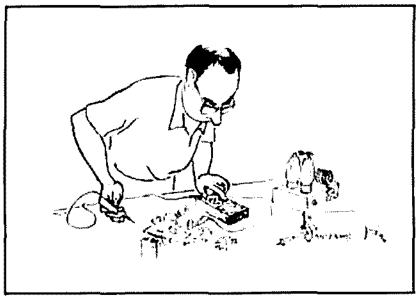
1. Tom McMullen, W1SL, "Elmer's Notebook," *Ham Radio*, September 1988, page 110.

Ham Radio Techniques



Bill Orr, W6SAI

ANTENNAS, GFI, CAPACITORS, AND FUNDAMENTALS

It was a so-so year for DX. The high MUF provided DX openings on 10 meters (sometimes), but the irregular outbursts of the sun wiped out the HF bands for days at a time. The 6-meter DXers were happy because when the HF bands pooped out, often as not the 6-meter band was open for long-haul DX. It was truly a mixed bag of propagation for 1989. Let's hope Old Sol settles down and provides some good stable HF/DX conditions in the coming year!

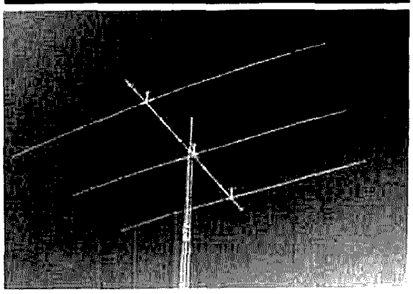
KØBIT's 40-meter "Death Ray"

Pete, KØBIT, decided he would build a 40-meter Yagi the "right" way (see Photo A). The three-element monster is constructed on a 48-foot boom consisting of two 24-foot sections of 3-inch OD by 0.125-inch wall aluminum tubing. A 12-foot long sleeve connects them together and provides additional strength at the center of the boom. The spacing between elements is 18 feet, and the extra 6 feet on each end of the boom are used for side guys on the elements.

The elements are made of 1.5-inch tubing telescoping to 1 inch, providing a mild taper ratio. Each element is guyed overhead to one 30-inch vertical post centered on the boom and is also guyed in the horizontal plane back to the boom on each side. This provides a sagless element. The guys are made of Phillystran Kevlar™ rope and are electrically transparent. Element dimensions are taken from the *Radio Handbook*.[1]

Pete says, "This beam is not something you can whip up in your garage, since a great deal of custom machine work and heli-arc welding has to be done for the special fittings. The effort was worth it. Forty meters is a whole new band with this beam. I can work Europe consistently and can break through the East Coast on difficult contacts!"

PHOTO A



KØBIT's 40-meter beam is built on a 48-foot boom. No element sag here!

WØSVM's 17-meter "Rabbit Ears"

No big beam for you? Well then, how about the "Rabbit Ears" antenna built by Jack, WØSVM. The design of the center-loaded V dipole is shown in **Figure 1**. Jack cuts a half-wave copper (or aluminum) tubing dipole in half and mounts it as shown. This particular model is cut for the 17-meter band. A framework of 1 by 2-inch lumber holds the tubing in position. A tapped coil connects the dipole halves and a small link coil is adjusted to frequency with a dip oscillator. The final step is to apply power to the antenna and adjust the coil coupling and antenna tap for lowest SWR on the line. Jack adjusted his antenna at 18.120 kHz; it covers the narrow band nicely.

GFI interference

A while back I reported cases of Ground Fault Interrupter (GFI) interference and queried readers about this problem. Here are some of the replies I've received:

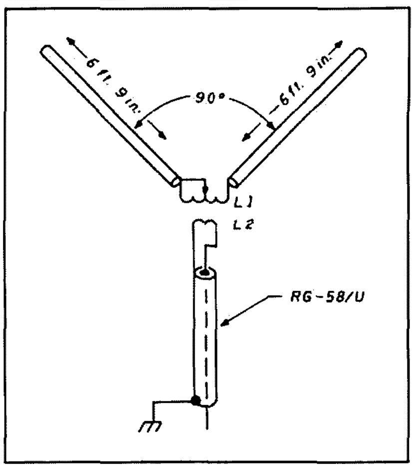
Ralph Dieter, K1RD, "I solved the GFI problem in my house by placing a ferrite tube (the equivalent of about 15 cores) on the neutral line to the GFI device. This appears to place enough impedance in the line to stop rectified signals from unbalancing the neutral circuit."

Bob Paine, W7RX, "The GFI indicator operates on an imbalance of about 5 mA between positive and neutral, and is very sensitive to RF. My cure was to place 0.003 μF, 1.6-kV (AC rated) ceramic capacitors from positive and neutral to ground. The capacitors are mounted in a two-wire plug inserted into the GFI unit."

Mike Schultz, KSØT, "The GFI unit is very susceptible to RF in the power line. I use a center-fed dipole antenna, 51 feet on a leg, fed with ladder line. When I use it as a dipole, I don't encounter any trouble. But when I short the feedline together and use the antenna as an end-fed wire on 160 meters, the GFI pops as soon as I press the key."

Mike's solutions include using a

FIGURE 1



WØSVM's "Rabbit Ears" antenna. Dimensions are for the 17-meter band. L1: 20 turns no. 12, 2-1/2" diameter, 6 turns per inch. Alligator clip adjusts coil to resonance. L2: 5 turns of hookup wire over the center of L1.

balanced antenna, using ground radials or counterpoise wires plus a good electrical ground connection for an end-fed antenna (or vertical), and avoiding expensive GFI breakers built into the panel. He recommends GFI receptacles with minimum wiring on their load side instead.

Mike notes that those who live in trailer parks or marinas should experiment with different types of RF grounds or counterpoises. He also suggests you avoid a resonant length of extension cord to feed AC power to your vehicle or craft.

The 1-farad capacitor

It's not hard to buy a 120,000-μF capacitor. (See any large distributor's catalog.) But how about a 1-F capacitor (1,000,000 μF)? There is one made by Nippon Electric that costs just a few dollars. My friend Joe, W8IIP, dropped one in the mail for me. This super capacitor can store enough charge to enable it to serve as a backup power source for memory and processor circuits in computers.

The construction of the super capacitor is unusual, but quite simple. The charge is stored in layers of activated charcoal with a very large surface area. The layers are separated by a porous plastic film. The electrolyte is sulfuric acid. A single capacitor has a maximum breakdown voltage of about 1.2, so units are stacked in series to provide higher working potentials. The capacitor isn't polarized.

I don't know what to do with my 1-F capacitor, so I keep it on the operating desk to overawe the humble.

All about electricity

The no-code license scheme, which includes a beefed-up technical quiz, is on the horizon. It looks as if we should pay attention to electrical fundamentals. Gadgets like 1-F capacitors seem to indicate that life is getting complicated. Attention to fundamentals — that's the secret path to knowledge!

Joe, K1REC, pays plenty of attention. Here are his remarks, condensed from the May issue of *World Radio* magazine. Joe and I will be pleased if the following technical information helps some would-be Novice achieve his license.

Joe says, "I've been fiddling with electricity for 50 years! I'd like to pass along some of my vast knowledge about this stuff.

"Electricity is manufactured in power plants where it is fed into wires wrapped around large drums. Some electricity, like that used for lightning does not need to go through wires. This kind of electricity isn't manufactured, but just hangs around loose in the air.

"Electricity makes a low humming noise. This noise may be pitched differently for doorbells, telephones, etc.

"Electricity must be grounded before it can function — except in airplanes, which have their own arrangements.

"Although electricity doesn't leak out of an empty socket, you can stick your finger in it and tell that it's there. Electricity is made out of two ingredients, positive and negative. One travels along a wire covered with white plastic, the other along a wire covered with black plastic. The wires connect to a device called a plug, in which the ingredients are mixed to form electricity.

"The electric switch contains a vise grip that squeezes the wire very hard so the electricity can't get through. Opening the switch releases the grip and lets the electricity flow.

"Electricity goes into a light bulb where we can actually see it! It is enlarged many times by the curvature of the bulb, which acts as a magnifying glass.

"Finally, electricity may be stored in boxes called batteries. In big batteries the electricity is shoveled in, while in small batteries it is packed in flat."

This concludes Joe's "Lessons on Electricity," part 1; I'm sure we're all looking forward to part 2.

All about vacuum tube logic

No kidding. Folks are building high class stereo amplifiers with *tubes*! Amplifiers ranging from 45 to 500 watts are available. The itty-bitty amplifiers use 6CA7s or 6550s. Bigger jobs use 6L6GCs or 807s. The number one amplifier uses a pair of class A carbon plate 845s. Wow! Music lovers seem to be the major buyers. The manufacturer is: Vacuum Tube Logic, 4709 Brooks Street, Montclair, California 91763. Too bad the days of amplitude modulation are past — it sounds as if the 845 amplifier would make a good modulator for a pair of 203As!

The Measurements Corporation dip meter

The Measurements Corporation HF

dip meter is a rare find at swap meets or flea markets. The device has an indicating meter and a compact power supply in a metal cabinet, plus a remote dip meter head. Seven plug-in coils cover the range from 2.5 to 420 MHz. The advantage of this unit over the conventional Millen dip meter is its compact remote head, which will fit into areas too small to permit the use of the Millen device. You're lucky indeed if you can pick up the Measurements Corporation unit (as I did a year or so ago).

One unfortunate aspect of the remote head is that the cable connecting it to the power supply is "hot," and moving the cable (or even the power supply) can affect the frequency of the tiny oscillator. The cure is to wrap the cable from the supply to the head through a ferrite core. I used one of the snap-apart cores, with six turns of the cable wound through it. That decoupled the RF head from the power supply, and provided more accurate readings that were less affected by the position of the user and the supply relative to the circuit being examined.

It's possible to remove the knob, the front of the housing, and the dial in order to reach the variable capacitor. If your unit is like mine, the rear capacitor bearing is caked with dried lubricant. Remove this with a small screwdriver or pin; then coat the bearing liberally with Lubriplate® or some other electrical grease. This will improve the stability of the oscillator.

Intermittent operation

On occasion you'll find that the dip oscillator stops operating. That is, the meter reading gradually drops to zero, or even goes negative. Tapping the oscillator head usually starts things going again. In my case, this annoying symptom was caused by poor connections in the plug-in coil. The coil wires are attached to the plugs by means of rivets, and electrical continuity is achieved through the riveted connection. Clean the soldering lug inside the form and the plug arm on the outside and solder a very short jumper between them, making an electrical short across the rivet.

After you've done these simple maintenance chores, your oscillator will be as good as new.

The Dead Band contests

Answers have been trickling in to the various little quizzes given in this column. Here are more "winners" who are heads up in quiz solving:

The five-resistor black box: WD6DUD, WØHJI, KØAS, W5ECB, W2LYH, K3TX, N3GDE, WBØTCZ, W8MQW, W8FBH, WA6JTD, N9DEO, KA2ZGW, K3GCM, N2JHS, W3LOY, K3GCM.

The jar of transistors (419 transistors in the jar):
W3DZH, WØHJI, K3TX, N3GDE, W8MQW, WA6JTD, N9DEO, K3GCM.

The bridge of multiple resistors (1.579 ohms): WD9FAQ, WB8WTS, W2TT, AA5AN, KB2WN, K4SE, W4EHU.

The coax cable puzzle: W6SIV, W2TT.

Congratulations, people!

REFERENCES

1. Bill Orr, W6SAI, *Radio Handbook*, 23rd edition, 1986, pages 24 27. Available from the **HAM RADIO** Bookstore for $26.95, plus $3.75 shipping and handling.

✓ 170

AN AUDIO PATCH PANEL
FOR THE MULTIMODE STATION

By Lewis F. McIntyre, KB6IC, 3711 Gayle Avene, Omaha, Nebraska 68123

I began operating teletype six years ago and discovered quickly that switching from RTTY back to SSB could be a real nuisance. My mic connectors weren't really made to stand up to frequent changes and the speaker connections on the back of my rig were inaccessible. These problems became worse as I added VHF packet capability.

A number of solutions have been proposed. However, most address only the RTTY/packet problem and limit their solutions to a choice of two transceivers.[1]

My solution was a simple, but extremely useful, addition to my shack called an audio patch panel. This unit lets you connect any audio source to any audio load in the shack. It controls the HF and VHF keylines so the HF and VHF transceivers can be keyed by any of the available microphones, CW key, toggle switches, or computer PTT lines — depending on your operating mode. I also gained some new capabilities along the way.

How it works

The patch panel design is very basic. It's a simple switch matrix made up of eight 12-pole rotary switches. You can find all the parts at Radio Shack; the total cost is about $30. The circuit diagram for the switch matrix is shown in **Figure 1**. For simplicity, I've shown only four of the eight switches. Audio loads (mic jacks of the HF and VHF sets, speakers, inputs to modems and patches) are connected to the arms of the switches; audio sources (output of the HF and VHF sets, microphones, outputs of modems and patches) are connected to the contacts of the rotary switches. With this arrangement, only a single source can ever be connected to any load — although all eight loads can be connected to any source. This is important because most sources don't like to be connected in parallel with others.

All audio connections run through two 2×4 phono jack panels on the back of the unit. My unit is wired with the sources on the top row and the loads on the bottom row. To accommodate standard connectors and reduce the number of wires in the shack, I've added five microphone four-pin jacks. The three mic jacks on the back accommodate the HF and VHF mic lines, and the AEA PakRatt audio output; the two on the front accommodate both mics. These are connected internally in parallel with their corresponding phono jacks on the back.

The speaker lines go through a normally closed stereo headphone jack, in series with the line to the phono jack. I used the right and left-most load jacks for the speakers. This way, I can use headphones without interrupting other accessories — like the PakRatt.

Besides the audio switch matrix, two more rotaries (S9 and S10) control the keylines (see **Figure 2**). Because my HF transceiver keys differently from the VHF transceiver, I use a double pole six-position rotary for keyline switches. One pole is connected to mic PTT and the other to the CW key jack. Two positions on S9 and S10 connect to either side of an SPDT toggle, S11. This switch is useful for handling VHF to HF relay operations. (More on that mode later.)

Two diodes, CR1 and CR2, prevent the HF and VHF rigs from interacting when they are connected to the same keyline. Depending on your rig, it may be necessary to reverse their polarity or eliminate them entirely.

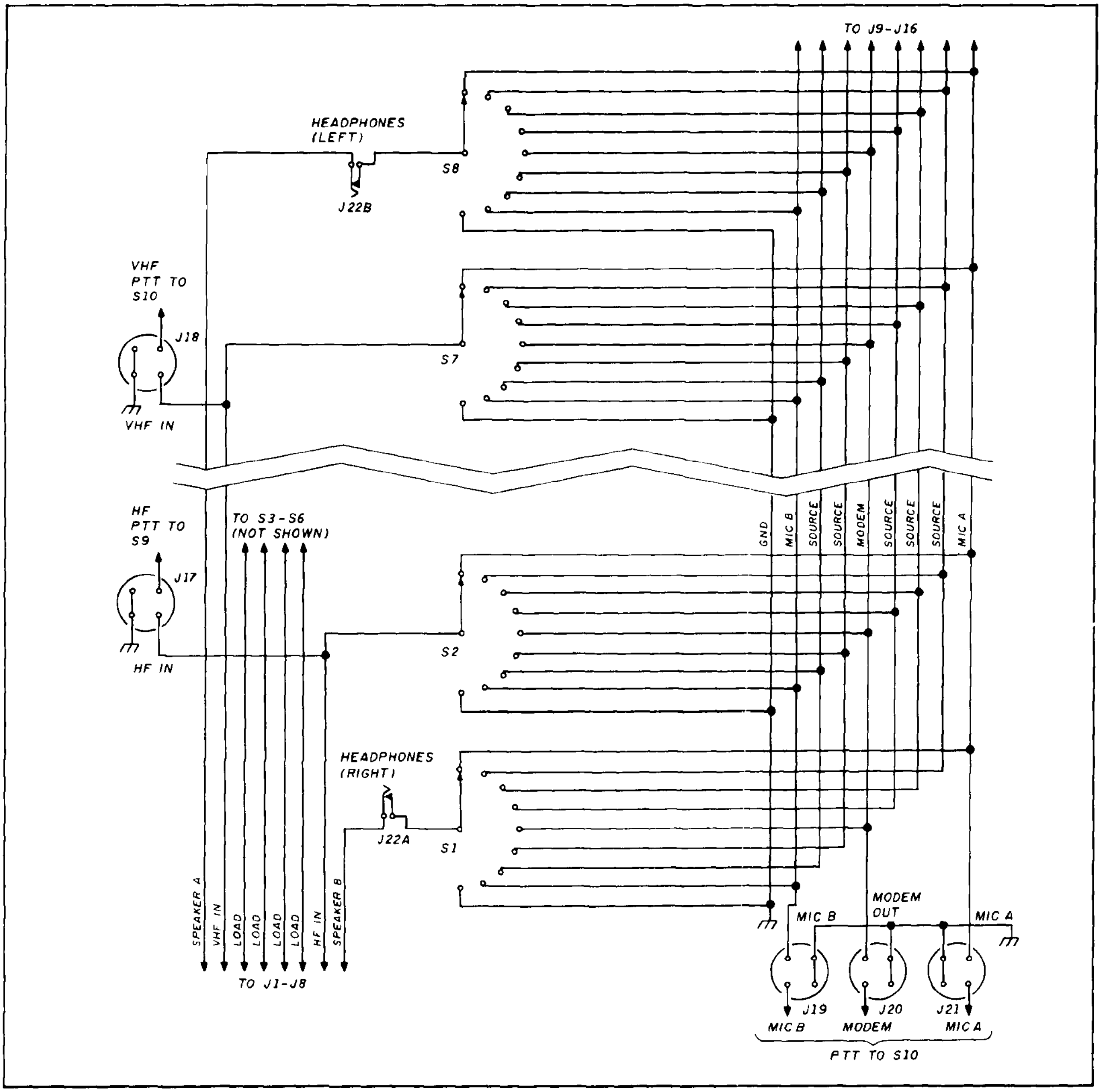
You may wish to review your station setup to see if you want to add or alter some of these "customizing" features. I tried to keep the order of connections to the back panel as general as possible so I could add or change equipment without having to rewire.

Assembly

This audio patch panel was built into a Radio Shack 3″ × 8″ × 6″ project box. The audio bundles run down both sides of the cabinet, left-side jacks to left-side switches and right-side jacks to right-side switches.

Wiring the audio switch array is the most tedious part of the construction. Use short lengths of single conductor wire to connect each switch contact to its corresponding contact on all the other switches. You need to connect only nine contacts — eight loads and ground. When this is done,

FIGURE 1



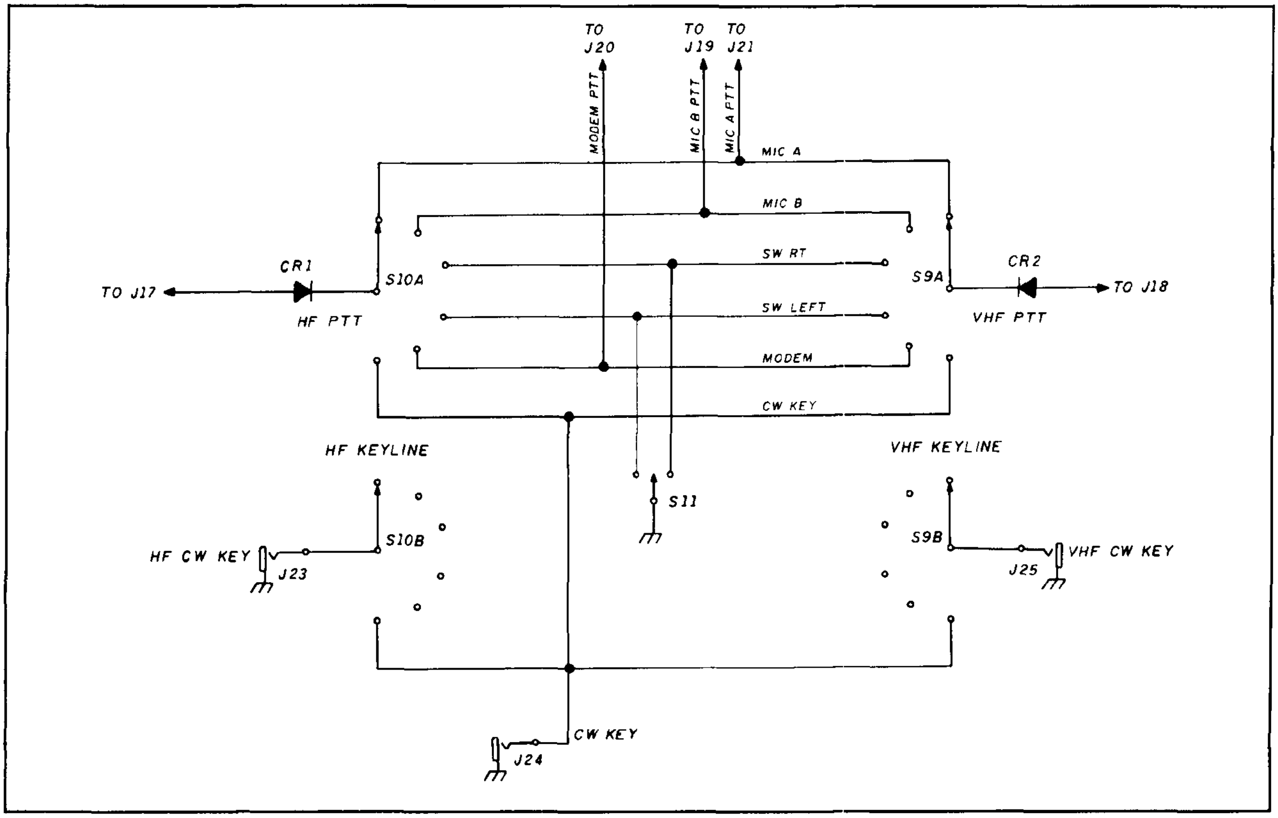
Schematic of the audio switch matrix.

check all connections for shorts and opens. Then, using two-conductor shielded audio cable, connect one conductor to the left-hand audio source on the upper row of phono jacks on the rear chassis and the other conductor to the audio load jack directly below. Route this cable to the switch where the source will be connected. Solder the source line to switch position no. 1 and the load to the normally closed contact to the stereo headset jack. Route a short length of single conductor cable from the jack to the switch contact.

PARTS LIST

Cabinet	*3x8x6-inch aluminum*	*(Radio Shack 270-274A)*
J1-J8	*2x4 phono jacks*	*(Radio Shack 274-370)*
J9-J14	*four-pin mic jacks*	*(Radio Shack 274-002)*
J15-J17	*one-conductor NO jack*	*(Radio Shack 274-255A)*
J18	*two-conductor NC jack*	*(Radio Shack 274-250)*
S1-S8	*one-pole 12-pos rotary*	*(Radio Shack 275-1385)*
S9-S10	*two-pole six-pos rotary*	*(Radio Shack 275-1386)*
S11	*SPDT toggle*	*(Radio Shack 275-620)*

FIGURE 2



Schematic of the HF/VHF keyline control.

Do likewise on the other side of the box for the right-hand jacks. This completes the special speaker wiring.

For the remaining pairs of source and load plugs, connect the two conductor cables from the plug pair to the switch rotor and contact points. Ground the shield at the phono plug block and at the ninth (ground) switch contact. Because all switch contacts are connected together, this accomplishes all the wiring for this source/load pair. The result is a single cable connected to each switch. When you've finished, check carefully for shorts and continuity, and then bundle the cable runs together with cable ties. Add the special connections to the modem, HF, VHF, and mic jacks.

Wire the keylines when the audio wiring is complete. You can do this with single conductor cable; the process is fairly self-explanatory. After you've completed this step, check again for shorts and continuity.

Wiring the station

I tied the following items together: HF transceiver, VHF transceiver, Heath SB-634 phone patch, AEA PK-232 digital data converter, and three speakers. I used to have a stereo tape recorder on the patch so I could record two channels. Because I added a third HF receiver and speaker, one channel (record and play) had to go. You also might want to add audio CW filters and VU meters.

Use a good grade of audio cable to tie everything together. I purchased new cable in 6-foot lengths. It was surprisingly inexpensive, considering that it came with installed connectors. This cable is available with either double-ended phono, or phono to miniature phone plug connectors. I ran the cables together in bundles behind the station console. Avoid bundling them with antenna coaxial cable or power lines, however; that's asking for hum and RF problems!

I used a small stereo amplifier (Radio Shack SA-10) between the speaker terminals on the patch and the speakers. This lets me keep volume at a comfortable level, independent of what level the various loads might want.

The keylines require PTT connections to each transceiver. This is handled through the special mic connectors on the rear panel for HF and VHF transceivers. You may require connections to each rig's CW key. Some transceivers key CW separately from the mic PTT (mine did) and need this connection. Others key in parallel with mic PTT and won't need it. Check your rig to make sure.

Using the patch panel

Each transceiver requires three switch selections:

- Connect an audio source to the transceiver's input. Do this by locating the switch corresponding to the transceiver input and rotate it to one of eight sources. For my configuration that can be mic A or B, phone patch output, modem output, HF or VHF output. With this configuration it's impossible to connect two sources to the same load.
- Connect the transceiver's audio output to one or more loads. Do this by selecting a switch corresponding to

the load you wish to connect (speaker A or B, HF or VHF input, phone patch, or modem input). You may connect as many loads as you need, usually the speaker plus one more.

- Connect the transceiver's keyline to a keying source. This can be mic A or B PTT, SW11 left, SW11 right, modem PTT, or CW key.

Results

I expected numerous headaches with this arrangement — like crosstalk between the different lines, RF pickup, and 60-Hz hum. To my amazement, I had only some minor RF pickup by the SA-10 amp while operating on 40 meters. You should have the same results if you use a good grade of audio cable to tie it all together and have a good ground at both ends of the audio cables inside the box.

I have used this unit for:

- HF/VHF relay. In this mode VHF out is connected to HF in, VHF in to HF out, HF keyline to the left side of the toggle S11, and VHF keyline to the right side of S11. When S11 is placed in the left-most position, all signals received on VHF are relayed onto HF; when it's in the right-most position, HF is relayed to VHF. This lets you use your station as an HF/VHF repeater under manual control. While this isn't as sophisticated as some systems described in other articles,[2] it does provide a powerful capability to link local VHF stations into long-haul HF circuits.
- VHF phone patch. Phone patches, like the Heathkit SB-634 that I use, are easy to place on line with HF equipment. However, I found that VHF patches are extremely useful as well. When the "Connie" operated off San Diego, I could easily raise my home QTH via simplex frequencies or wide area repeaters in San Diego which didn't have autopatch. The audio quality is vastly superior to HF.
- RTTY and packet. My preferred mode is RTTY. I also do a lot of RTTY and FAX SWLing using a vintage Hammarlund HQ-180. That unit lives on position 5 on my patch panel, and I can switch easily to that receiver when I need more frequencies than my ham-bands-only TS-830S can provide. Switching between two HF receivers and the VHF rig is a breeze with this patch panel.

Future growth

I have considered expanding this unit beyond the eight switches, adding some internal VU meters, and moving the speaker amplifier into the unit. A bank of 1-of-10 (*not* BCD!) thumbwheel switches might make for a more compact panel. But this unit has worked so well as is, that I haven't made the move to transfer these thoughts off the drawing board.

Summary

This audio patch panel has added to the flexibility of my multimode station enormously and has eliminated the rat's nest of different connectors to get all the equipment to work together. Why not make one of your own? It's inexpensive and easy to build. hr

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2. David F. Allen, W1VKZ, "Breakthrough in Boston: The Birth of Crosslinking," 73, January 1984, pages 10-14.

A NEW ADDITION FOR YOUR TNC

By Joel Eschmann, K9MLD, 6964 Meadowdale Drive, Hartford, Wisconsin 53027

Over the last few years I've become very active on packet. I have a number of TNCs and use them at home, at my summer place, and in my camper. I use a number of terminals and computers available to me and I find the big sore spot with many of them is the "connect bell."

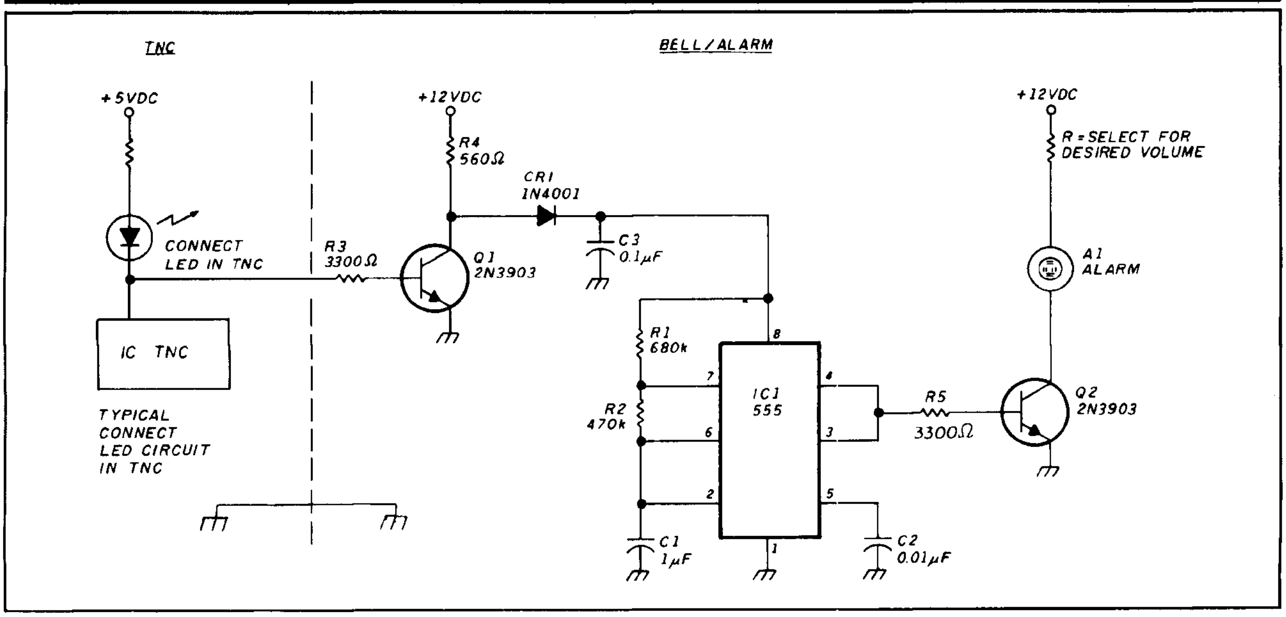
The bell is either too quiet or doesn't exist. When the packet equipment takes over after a connect, I want it to let me know someone is there so I can respond. I hope those of you with similar problems will find this article of interest.

Most current TNCs have a connect light or indicator. To make use of this element of the TNC and the existing cir-

PARTS LIST

IC1	NE555 Radio Shack 276-1723
R1	680-k 1/8 watt resistor
R2	470-k 1/8 watt resistor
R3,R5	3300-ohm 1/8 watt resistor
R4	560-ohm 1/8 watt resistor
C1	1-μF capacitor 15 volt minimum
C2	0.01-μF capacitor 15 volt minimum
C3	0.1-μF capacitor 15 volt minimum
A1	Alarm Radio Shack 273-066
RY1	Relay 12-volt Radio Shack 275-248
CR1	Diode 1N4004 Radio Shack 276-1103
Q1,Q2	NPN 2N3053 Radio Shack 276-2030

FIGURE 1



Schematic of the connect buzzer circuit.

cuits, I've developed a very simple device which adds an accessory the TNC manufacturers forgot. The circuit is very basic and uses the popular 555 timer available from Radio Shack (which also carries a choice of bells, alarms, and breadboard items).

As Figure 1 shows, the circuit can fit into the TNC. The bell, because of its size, is best mounted on the outside of the cabinet or in a separate box. You may want to provide a switch to select different bells at other locations. Exercise a little caution if you use bells not compatible with the one mentioned here; the current drain may be in excess of the capabilities of the 555 and could damage it.

Circuit description

Q1 is a DC switch which controls the 555 timer (IC1). When voltage is present at the base of Q1, the transistor conducts and the voltage at the collector goes to zero. At the time of the connect, the internal circuits of the TNC cause current to flow in the CONNECT LED. The voltage at the base of Q1 goes to zero and the transistor turns off. This causes the collector voltage to rise to the supply voltage. The supply voltage then applied to the 555 timer causes it to start, and also sounds the bell. After a time determined by R1, R2, and C1, the 555 timer times out and the bell stops. The 555 timer allows for a timed alert that's long enough to attract your attention. If you wish to change the timing, alter the values of R1, R2, and C1. Note that this circuit won't function if R2 is greater than one-half R1. The circuit has an automatic reset that triggers when the TNC disconnects and returns the circuit to an off state.

I've used the basic internal connect circuit from my AEA PK-88 for this illustration. This circuit may vary from manufacturer to manufacturer, but understanding the operation of this optional circuit will enable you to install it in your TNC.

I have found this circuit very useful and I hope you will too. *Note: Making modifications to your TNC may void your warranty. Check with the TNC manufacturer Ed.*

IDENTIFYING KERCHUNKERS AND OTHER INTERFERENCE

Finding the fingerprints of unknown signal sources

By Richard R. Regent, K9GDF, 5003 South 26th Street, Milwaukee, Wisconsin 53221

A *kerchunker* is a person who turns on a repeater's transmitter briefly without identifying himself. He will sometimes do this to see if he can reach a repeater from various locations, or at random times to ensure that the repeater and his transceiver are working. However, transmitting a signal without identifying is illegal.

Kerchunkers are difficult to pin down because their transmissions are short. A method for identifying momentary signals should make it easy to determine the origin of longer duration signals, ranging from accidental keyups to blatant jamming.

Warren Schall, K9IZV, told the Milwaukee Repeater Club about a technological tool that can identify kerchunkers on 2-meter repeaters. The detective equipment consists of a Micro Control Specialties receiver (Model MR4), a Heathkit® Model 4850 digital memory oscilloscope, and an IBM PC compatible computer.

Receiver selection for this setup isn't critical. Most repeater receivers have test connections for the points that have the two signals you need to track down kerchunkers — the discriminator and signal strength alignment. Some receivers have convenient external outputs with two BNC coaxial cable connections.

The digital memory oscilloscope (DMO) turns your PC into a powerful dual trace 50-MHz digital storage oscilloscope. Scope settings are controlled from the DMO front panel and identified by LED indicators. Once you've fed the proper signals from the receiver into the DMO, and connected it to the computer via its RS-232 port, the signal-handling magic takes place.

The computer monitor gives a visual display of the signals, taking the place of the old familiar bench scope display screen. You can display two channels on graphic 8 × 10 division graticules to obtain readouts of voltage, time, and frequency automatically at any point on a waveform. Your computer should have at least 128K of RAM and a graphics card. This configuration of equipment can measure signals with timebases ranging from 20 seconds to 10 milliseconds per division; 50 milliseconds per division works well for studying kerchunkers.

The DMO, set for one-shot triggering on a rising signal, is ready to capture and store data to memory. It stores an entire waveform as digital numbers, using 256 amplitude and time coordinates. A transmission a fraction of a second long gives you enough time to get a complete file on a kerchunker.

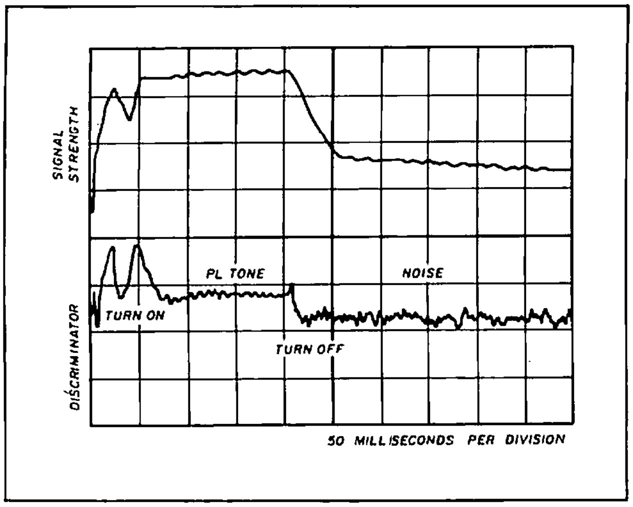
A freeze display of the signal on the monitor shows the unidentified transmitter's fingerprint (see **Figure 1**). The system can eventually be programmed to match the signal from a kerchunker, or other unidentified source, with records in a database of characteristic waveforms of transmitters in the area. Warren explains, "Each transmitter has a characteristic set of parameters, sometimes called a signature."

There are a few key factors to look for when analyzing waveform signatures:

- **Initial transient waveforms**. The momentary frequency changes a transmitter undergoes as it stabilizes after being turned on produce a unique blip on the monitor screen. The phase lock loop time constants used in most modern FM transmitters generate fairly similar signatures from a given unit each time it's keyed.
- **Frequency calibration accuracy**. The difference between the transceiver-transmit and the repeater-receive frequencies, in cycles per second, as indicated by the receiver discriminator output DC level.
- **Frequency and amplitude of a Private Line (PL), subaudible tone, or an extraneous hum**. The frequency of the subaudible tone can be found easily by expanding the waveform on the computer screen. Count the cycles in a given time period, or find the time period for a number of full cycles, and then take its reciprocal to get the frequency of the tone. The tone may match one of several used in the area, but could be off frequency enough or have such an unusual amplitude that it provides positive identification.
- **Audio deviation level**. This level is normally around 4.0 to 5.5 kHz.
- **Absolute strength of the signal.**

These are the five main factors of identification, but there are also a few special considerations. By monitoring the signal strength on the second limiter output of the receiver, it's sometimes possible to determine if the transmitter is mobile or fixed. This shows up as a wavering strength indication. Even certain transmitters designed with turn-on

FIGURE 1



An example of a freeze display of a signal on the monitor showing an unidentified transmitter's fingerprint.

Y1: DC (normal)
500 mV/div
Offset: +2.38 volts

Y2: DC (normal)
1.0 volts/div
Offset: +3.24 volts

Timebase: <->
50 ms/div
Trig source: Y1
Trig slope: (+)
Trig level: +0.34 volt
Trig mode: single manual trigger
2lim = 500 mV; 50 ms
disc = 1.0 volt; 50 ms
F5:Memory F6:Average F7:Exit to system F8:Next menu

delays that may mask part of the initial transient use different time delays which give clues for identification. Again, time and waveform shapes reveal interesting particulars.

Various units of the same model transmitter may have similar waveforms; however, they can usually be distinguished from one another by analysis of their signatures. The detective work takes time, but once a signal is captured it can be documented by unique waveforms which are stored on floppy disk and printed out for later analysis or comparison. With more refinement, you could apply this digital technology to the HF bands to track down jamming and intentional interference. For the time being, however, the research continues on VHF repeater frequencies.

The signals for our club meeting demonstration traveled from the digital scope to the computer with RS-232 cable, but signals could be transmitted over packet radio to distant monitoring control operators. Control commands could then arm or disarm the scope system and request waveform data. **hr**

Note: This technology has the potential to identify many types of interference. Future units of this sort may be mobile and used to track down CATV, power line, and other types of interference. Ed.

✓ 155

DX Forecaster

Garth Stonehocker, KØRYW

DXING FROM WINTER ANOMALIES

Winter is the enhanced DX season because it usually has higher signal strengths and lower thunderstorm noise than the summer. This is particularly true on the lower bands. The anomaly of this ordinarily improved wintertime signal is the five to six day period of 20 to 40-dB weaker signals (more like summertime) through the mid-to-high latitude paths which provide our communication links to European, Asian, and Japanese Amateurs. I've discussed the reasons for this anomally in previous December columns; it affects those latitudes in 90-degree increments of longitude. The longitudes directly opposite (180 degrees) each other have higher than normal winter signals. Those longitudes in between (90 degrees), but again across from each other, have lower than normal winter signals. During the five to six days (or longer) of the anomalous absorption event, the areas rotate in unison 30 degrees (two time zones) per day. At the same time, they decrease from 65 at day zero to 30 degrees latitude (ending) in the five days of rotation of 7 degrees latitude per day.

To take advantage of the decreased absorption providing the strong DX signals on east, west, and transpolar paths, check WWV at 18 minutes after the hour, WWVH at 45 minutes after the hour, or the bulletin board to keep track of the daily geomagnetic A value during the winter (mainly January). When you hear an A value of 15 or higher, continue to listen daily until a STRATWARM and its location is given. Next, consult your maps to find the 90-degree position between the location given for the STRATWARM and its 180-degree companion. Coordinate your beam bearings and the DX path control points (1200 miles from the QTHs "on" the great circle) with the areas of lower absorption on both, or at least one, end of the path. If that area isn't right for your DX at this time, you can forecast — at shifts of 30 degrees of longitude to the west and 7 degrees lower latitude per day — when better conditions will prevail.

The occurrence of higher wintertime maximum usable frequencies (MUFs) is another geophysical winter effect that seems like an anomaly. While the D, E, and lower F regions have larger electron densities in summer, the daily maximum density of the F-region (which usually sets the day's MUF) peaks during the winter. This peak isn't as broad (measured by hours of the day) as it is in the summer, but it's narrower and higher. You have to be right there when the band opens (on 10 meters, for example) to catch these few hours. This same effect makes the one long hop transequatorial propagation (TE) possible in the evenings. But again, you must be watching and jump on fast. Remember, a raised geomagnetic A level increases the probability of TE openings.

Last-minute forecast

The first, second, and last weeks of December should have excellent higher frequency (10 to 30 meter) DX band openings. Look for both long skip and extra DX transequatorial openings from high MUF build-up during the day and evenings. Some short skip sporadic E openings might even help your DX. The lower bands should be best the second and third weeks of the month.

The Geminids meteor shower, which peaks on December 13th and 14th, will provide rates of 60 to 70 per hour. Optical observations may be difficult or impossible to make during periods of poor December weather, so determine the actual numbers by radio reception. A smaller version of the shower will occur on December 22nd. The full moon appears on the 12th, lunar perigee is on the 10th. Winter solstice is on December 21st at 2100 UTC.

Band-by-band summary

Ten, 12, 15, and 17 meters will be open from morning until early evening most days to most areas of the world. The higher band openings will be shorter and occur closer to local noon. Transequatorial propagation on the higher bands will probably occur toward evening, during times of high solar flux and disturbed geomagnetic field conditions.

You may find 20, 30, and 40 meters useful almost 24 hours a day. Skip distances and signal strengths may decrease during midday on days coinciding with these higher solar flux values. Expect good nighttime DX, except after days of high MUF conditions and during geomagnetic disturbances. Look for DX from unusual locations on eastern, northern, and western paths during this time. The usable distance on the lower bands should be somewhat less than 20 in the daytime and greater than on 80 at night.

Eighty and 160 meters will exhibit short skip propagation during daylight hours and lengthen for DX at dusk. These bands follow the darkness regions opening to the east just before your sunset, swinging more to the south around midnight, and ending up in the Pacific areas an hour or so before dawn.

DECEMBER

WESTERN USA

GMT	PST	N (Asia, Far East)	NE (Europe)	E (S. Africa)	SE (S. America)	S (Antarctica)	SW (New Zealand)	W (Oceania, Australia)	NW (Japan)
0000	4:00	17	30	12	10	10	10	10	12
0100	5:00	15	30	15	12	10	10	10	12
0200	6:00	17*	30	15	12	10	10	10	12
0300	7:00	20	30	17	15	10	10	10	17*
0400	8:00	30	30	17	15	12	12	15	20
0500	9:00	30	30	17	15	12	15	15	20
0600	10:00	30	30	17	17	15	15	15	30
0700	11:00	30	30	17	17	15	15	17	30
0800	12:00	30	30	20	17	17	17	17	30
0900	1:00	30	30	20	17	17	17	17	30
1000	2:00	30	30	20	17	17	17	17	30
1100	3:00	30	30	20	17	20	17	17	30
1200	4:00	30	30	17	20	17	17	17	30
1300	5:00	30	20	10	10	15	17	20	30
1400	6:00	30	15	10	10	12	20	15	30
1500	7:00	30	15	10	10	10	17	15	30
1600	8:00	30	15	10	10	10	15	20	30
1700	9:00	30	15	10	10	10	12	15	30
1800	10:00	30	17	10	10	10	12	12	30
1900	11:00	30	20	10	10	10	10	12	30
2000	12:00	30	30	10	10	10	10	10	15
2100	1:00	30	30	10	10	10	10	10	12
2200	2:00	30	30	12	10	10	10	10	12
2300	3:00	30	30	12	10	10	10	10	12

MID USA

GMT	MST	CST	N (Asia, Far East)	NE (Europe)	E (S. Africa)	SE (S. America)	S (Antarctica)	SW (New Zealand)	W (Oceania, Australia)	NW (Japan)
0000	5:00	6:00	17	30	12	12	10	10	10	15
0100	6:00	7:00	15	30	12	12	10	10	10	15
0200	7:00	8:00	15	30	15	15	12	10	15	15
0300	8:00	9:00	20	30	15	15	12	12	15	17
0400	9:00	10:00	30	30	17	15	15	12	15	20
0500	10:00	11:00	30	30	17	17	15	15	17	20
0600	11:00	12:00	30	30	17	17	15	15	17	30
0700	12:00	1:00	30	30	20	17	17	17	20	30
0800	1:00	2:00	30	30	20	17	17	17	20	30
0900	2:00	3:00	30	30	20	17	17	17	20	30
1000	3:00	4:00	30	30	20	17	20	17	20	30
1100	4:00	5:00	30	20	17	20	17	17	20	30
1200	5:00	6:00	30	17	10	15	15	17	20	30
1300	6:00	7:00	30	15	10	12	12	20	20	30
1400	7:00	8:00	20	15	10	10	10	17	17	30
1500	8:00	9:00	17	15	10	10	10	15	15	30
1600	9:00	10:00	20	15	10	10	10	12	12	30
1700	10:00	11:00	30	15	10	10	10	12	12	30
1800	11:00	12:00	30	17	10	10	10	10	12	30
1900	12:00	1:00	30	20	10	10	10	10	12	30
2000	1:00	2:00	30	30	10	10	10	10	10	15
2100	2:00	3:00	30	30	10	10	10	10	10	15
2200	3:00	4:00	30	30	12	10	10	10	10	15
2300	4:00	5:00	30	30	12	10	10	10	10	15

EASTERN USA

GMT	EST	N (Asia, Far East)	NE (Europe)	E (S. Africa)	SE (Caribbean, S. America)	S (Antarctica)	SW (New Zealand)	W (Oceania, Australia)	NW (Japan)
0000	7:00	30	30	17	12	12	10	10	20
0100	8:00	30	30	17	12	12	15	15	20
0200	9:00	30	30	17	15	12	15	15	30
0300	10:00	30	30	17	15	15	15	17	30
0400	11:00	30	30	17	15	15	17*	17	30
0500	12:00	30	30	17	17	15	17	17	30
0600	1:00	30	30	20	17	17	17	17	30
0700	2:00	30	30	20	17	17	17	20	30
0800	3:00	30	30	20	17	17	17	20	30
0900	4:00	30	30	20	17	17	20	20	30
1000	5:00	30	17	10	17	17	20	20	30
1100	6:00	17	15	10	12	20	20	20	30
1200	7:00	17	15	10	10	15	15	17	30
1300	8:00	20	15	10	10	12	15	12	30
1400	9:00	30	15	10	10	10	15	12	30
1500	10:00	30	15	10	10	10	17	15	30
1600	11:00	30	15	10	10	10	15	15	30
1700	12:00	30	15	10	10	10	12	17*	30
1800	1:00	30	17*	10	10	10	10	15	30
1900	2:00	30	20	10	10	10	10	12	30
2000	3:00	30	30	10	10	10	10	10	17
2100	4:00	30	30	10	10	10	10	10	15
2200	5:00	30	30	15	10	10	10	10	15
2300	6:00	30	30	15	10	10	10	10	17*

INTRODUCTION TO WAVEFORM GENERATORS PART 2

Astable (free running) multivibrator circuits

By Joseph J. Carr, K4IPV, P.O.B. 1099, Falls Church, Virginia 22041-0099

The circuits discussed in part 1 of this three-part series were aperiodic, meaning that an output pulse occurs just once in response to an input stimulus or trigger. Such circuits are said to be monostable because they possess only one stable state. An astable multivibrator (AMV) is free running. The output of the AMV is a periodic pulse or wave train. In a periodic signal, the wave repeats itself indefinitely until the circuit is either turned off or otherwise inhibited.

Astable multivibrators are oscillators. Waveforms available from the AMV include square, triangle, and sawtooth waves. Sine waves are also available from oscillator circuits. But because those circuits operate differently from the others, I won't discuss them here.

The nonsinusoidal AMV circuits will produce square, triangle, or sawtooth waves. When they are used as a clock to drive a very short duration monostable multivibrator (MMV), a pulse generator results. I'll begin my discussion of AMV circuits with square waves because the square wave generator is the most basic form of AMV.

Square wave generators

Figure 1A shows a square wave. Each time interval of the wave is quasi-stable, so you may conclude that the square wave generator has no stable states (is astable). The waveform snaps back and forth between −V and +V, dwelling on each level a duration of time (ta or tb). The period, T, is:

$$T = ta + tb \tag{1}$$

Where:

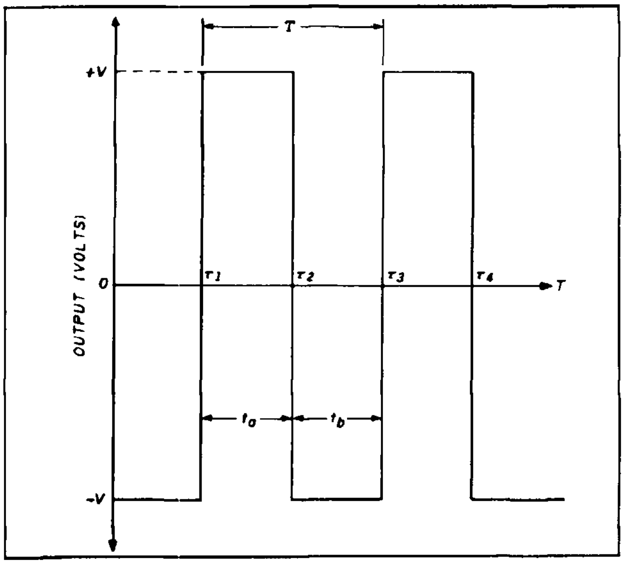
T is the period of the square wave (t1 to t3)
ta is the interval t1 to t2
tb is the interval t2 to t3

The frequency of oscillation (F) is the reciprocal of T:

$$F = \frac{1}{t} \tag{2}$$

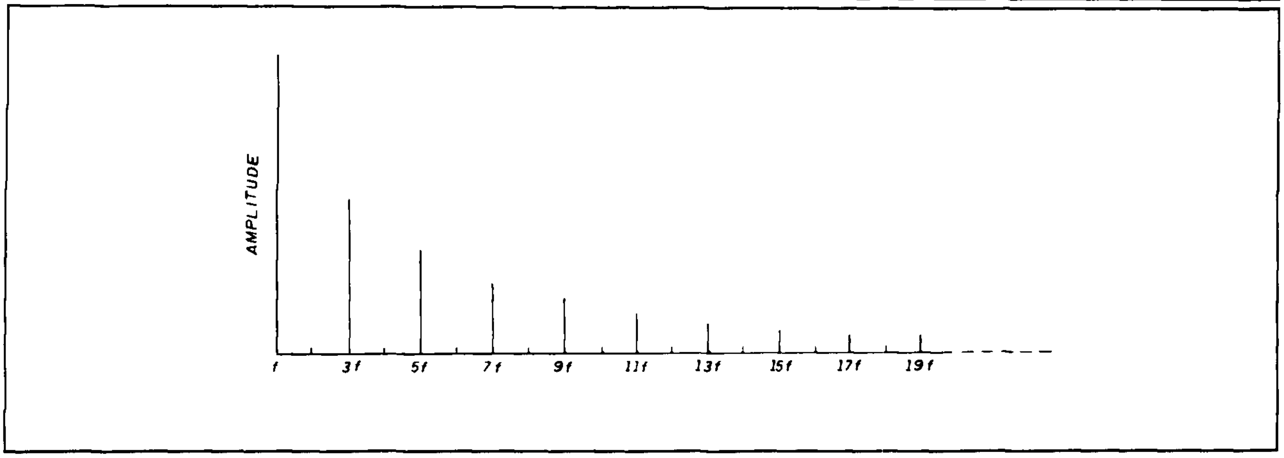
The ideal square wave is both base line and time line symmetrical. That means that $|+V| = |-V|$ and ta = tb. Under time line symmetry ta = tb = t, so T = 2t and f = 1/2t.

FIGURE 1A



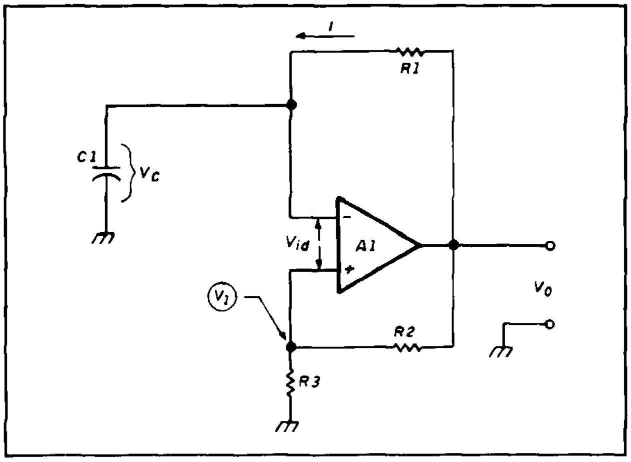
Representation of a typical square wave.

FIGURE 1B



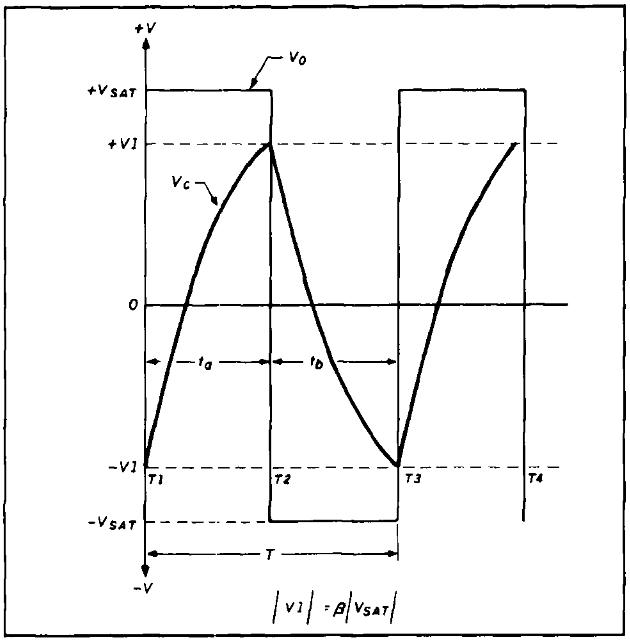
Bar graph depicting the Fourier series spectrum of a true square wave.

FIGURE 2A



A simple square wave generator circuit using an op amp.

FIGURE 2B



Timing chart for the circuit in *Figure 2A*.

All continous mathematical functions (including voltage functions of time) can be constructed from a fundamental frequency sine wave (f) added to a series of sine and cosine harmonics (2f, 3f, 4f, ... , nf). The mathematical expression of which harmonics are present, and their respective amplitudes and phase relationships, is called the *Fourier series* or *Fourier spectrum* of the waveform. The Fourier series is usually depicted as a bar graph spectrum as shown in **Figure 1B**.

In the ideal symmetrical square wave, the Fourier spectrum (**Figure 1B**) consists of the fundamental frequency (f) plus the *odd order* harmonics (3f, 5f, 7f, and so on). Furthermore, the harmonics are in phase with the fundamental. Theoretically, an infinite number of odd number harmonics are present in the ideal square wave. However, in practical square waves, the "ideal" is considered satisfied with harmonics to about 999f. That ideal is almost never reached due to the normal bandwidth limitations of the circuit. The rise time of the square waves is an indicator of harmonic content. The faster the rise time, the higher the number of harmonics.

The circuit for an operational amplifier square wave generator is shown in **Figure 2A**. The basic circuit is similar to the simple voltage comparator and the MMV. Like the MMV, AMV operation depends upon the relationship between V(– in) and V(+ in). In the circuit of **Figure 2A** the voltage applied to the noninverting input (V(+ in)) is determined by a resistor voltage divider, R2 and R3. This voltage is called V1 in **Figure 2A** and is:

$$V1 = \frac{Vo\ R3}{R2 + R3} \tag{3}$$

or when Vo is saturated:

$$V1 = \frac{Vsat\ R3}{R2 + R3} \quad (4)$$

Because R3/(R2+R3) is always a fraction, V1 < Vsat, and V1 is of the same polarity as Vsat.

The voltage applied to the inverting input V(−in) is the voltage across capacitor C1; i.e., V(C1). This voltage is created when C1 charges under the influence of current I, which is a function of Vo and the time constant of R1C1. Figure 2B shows the timing operation of the circuit.

At turn-on, VC1 = 0 volts and Vo = +Vsat, so V1 = +V1 = B(+Vsat). Because VC1 < V1, the op amp sees a negative differential input voltage, so the output remains at +Vsat. During this time, however, VC1 is charging towards +Vsat at a rate of:

$$V(C1) = Vsat\left[1\text{-}e\,\frac{(-t / R1C1)}{a}\right] \quad (5)$$

When VC1 reaches +V1, the op amp sees VC1 = V1, so Vid = 0. The output now snaps from +Vsat to −Vsat (time t2 in Figure 2B). The capacitor now begins to discharge from +V1 towards zero, and then recharges towards −Vsat. When it reaches −V1, the inputs are zero once again, so the output snaps to +Vsat. The output snaps back and forth continuously between −Vsat and +Vsat, producing a square wave output signal.

Using Equation 4 from part 1, the time constant required to charge from an initial voltage VC1 to an end voltage VC2 in time t is defined by:

$$RC = \frac{-T}{Ln\left[\dfrac{V - V(C2)}{V - V(C1)}\right]} \quad (6)$$

In Figure 6A the RC time constant is R1C1. From Figure 6B it's apparent that VC1 = −BVsat, VC2 = +BVsat, and V = Vsat for interval ta. To calculate the period T

$$2\ R1C1 = \frac{-T}{Ln\left[\dfrac{Vsat - BVsat}{Vsat - (-BVsat)}\right]} \quad (7)$$

or rearranging Equation 7:

$$-T = 2R1C1\ Ln\left[\frac{Vsat - BVsat}{Vsat - (-Bsat)}\right] \quad (8)$$

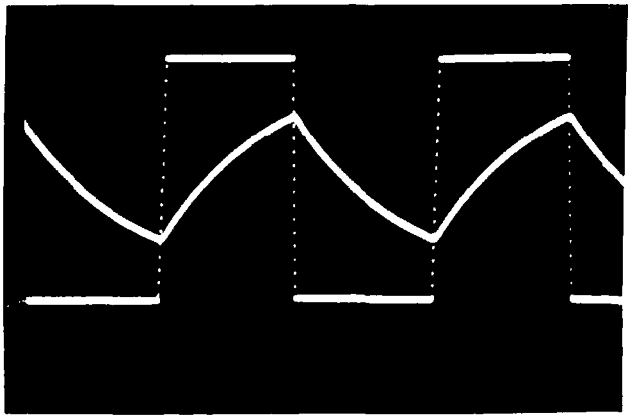
$$-T = 2R1C1\ Ln\left[\frac{1 - B}{1 + B}\right] \quad (9)$$

$$T = 2R1C1\ Ln\left[\frac{1 + B}{1 - B}\right] \quad (10)$$

Because B =R3/(R2+R3):

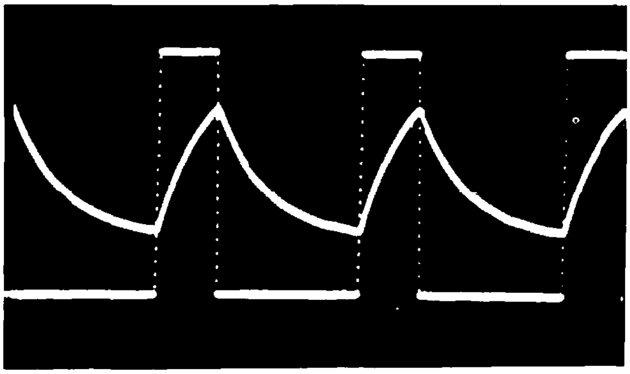
$$T = 2R1C1\ Ln\left[\frac{1 + (R3/(R2 + R3))}{1 - (R3/(R2 + R3))}\right] \quad (11)$$

PHOTO A



V_{out} of a 741 op amp square wave generator superimposed on V_c.

PHOTO B



V_a = +V.

which reduces to:

$$T = 2R1C1\ Ln\left[\frac{2\ R2}{R3}\right] \quad (12)$$

Equation 12 defines the frequency of oscillation for any combination of R1, R2, R3, and C1. In the special case R2 = R3, B = 0.5 so:

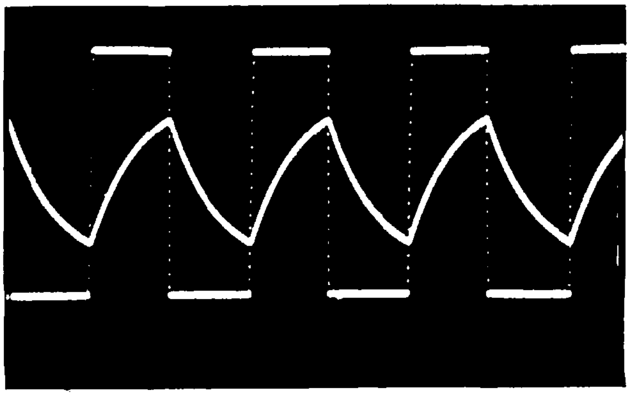
$$T = 2R1C1\ Ln\left[\frac{1 + 0.5}{1 - 0.5}\right] \quad (13)$$

$$T = 2R1C1\ Ln\left[\frac{1.5}{0.5}\right] \quad (14)$$

$$T = 2R1C1\ Ln\ [1.09] = 2.2R1C1 \quad (15)$$

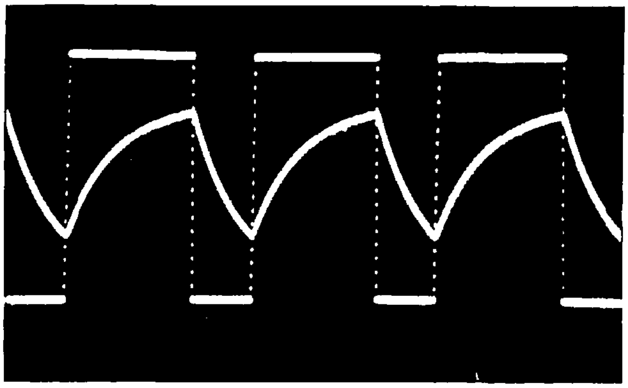
The circuit in Figure 2A produces time line symmetrical square waves (ta = tb). Photo A shows the output square wave superimposed on Vc for a 741 op amp square wave generator. If time line asymmetrical square waves are required, then you'll need a circuit like Figure 3 or 4. The circuit in Figure 3 uses a potentiometer (R4) and a fixed resistor (R5) to establish a variable duty cycle asymmetry. The circuit is similar to Figure 2A, but an offset circuit (R4/R5) has been added. The assumptions are that R5 = R1, and R4 << R1. If Va is the potentiometer output volt-

PHOTO C



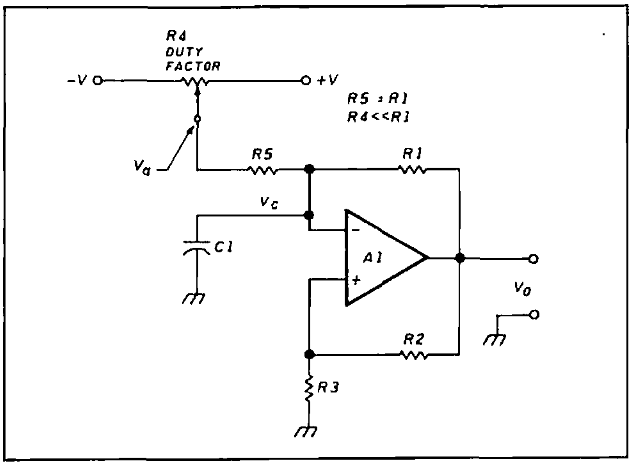
V_a = 0 volts.

PHOTO D



V_a = −V.

FIGURE 3



A circuit for generating asymmetrical square waves with a variable duty cycle.

age, C1 charges at a rate of (R1/2)C1 towards a potential of Va + Vsat. However, after output transition the capacitor discharges at the same (R1/2)C1 rate towards Va − Vsat. The two interval times are therefore different; ta and tb are no longer equal. **Photos B, C,** and **D** show three extremes of Va. They are: Va = +V (**Photo B**), Va = 0 (**Photo C**), and Va = −V (**Photo D**). These traces represent very long, equal, and very short duty cycles, respectively.

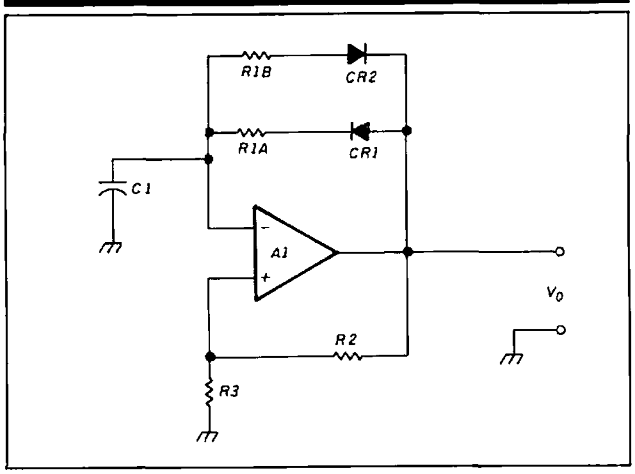
The circuit of Figure 4 also produces asymmetrical square waves, but the duty cycle is fixed instead of variable. Once again, the basic circuit is like **Figure 2A**, but with added components. In **Figure 4** the RC timing network is altered so the resistors are different on each swing of the output signal. During ta, Va = +Vsat, so diode CR1 is forward biased and CR2 is reverse biased. For this interval:

$$ta = (R1A)\ (C1)\ Ln \left[1 + \frac{2\ R2}{R3} \right] \qquad \textbf{(16)}$$

During the alternate half cycle (tb), the output voltage Vo is at −Vsat, so CR1 is reverse biased and CR2 is forward biased. During this interval R1B is the timing resistor, while R1A is effectively out of the circuit. The timing equation is:

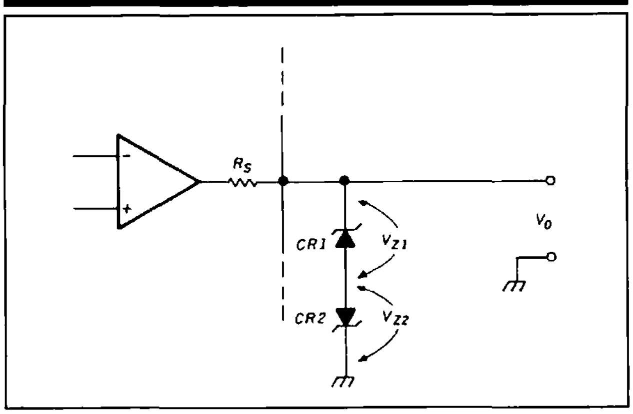
$$tb = (R1B)\ (C1)\ Ln \left[1 + \frac{2\ R2}{R3} \right] \qquad \textbf{(17)}$$

FIGURE 4



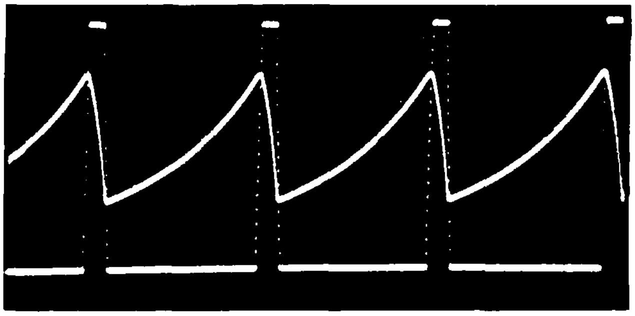
Another asymmetrical wave producer with a fixed duty cycle.

FIGURE 5



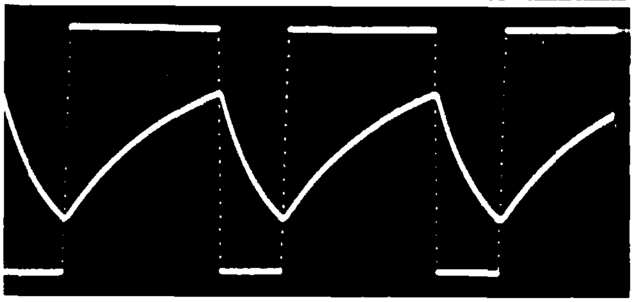
Using back-to-back zener diodes to clean up the square wave generator output.

PHOTO E



R1A/R1B = 10:1.

PHOTO F



R1A/R1B = 2.6:1.

the total period, T, is ta + tb, so:

$$T = (R1A)\ (C1)\ Ln \left[1 + \frac{2\ R2}{R3} \right] + (R1B)\ (C1)\ Ln \left[1 + \frac{2\ R2}{R3} \right] \qquad (18)$$

Collecting terms:

$$T = (R1A + R1B)\ (C1)\ Ln \left[1 + \frac{2\ R2}{R3} \right] \qquad (19)$$

Equation **19** defines the oscillation frequency of the circuit in **Figure 4**. **Photos E** and F show the effects of two values of the R1A/R1B ratio. In **Photo E** the ratio R1A/R1B = 10:1; in **Photo F** R1A/R1B = 2.6:1.

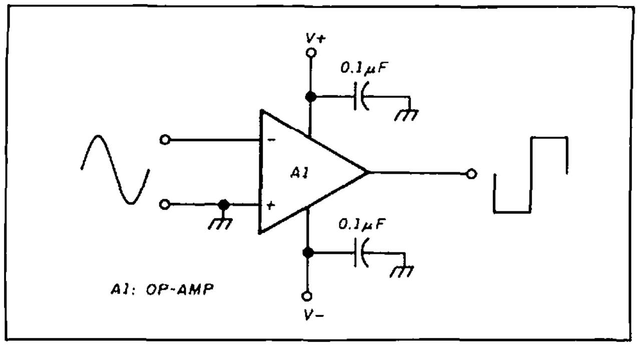
Output voltage limiting

The standard op amp MMV or AMV circuit sometimes produces a relatively sloppy square output wave. You can clean up the signal by adding a pair of back-to-back zener diodes (**Figure 5**) across the output. For each polarity the output signal sees one forward biased and one reverse biased zener diode. On the positive swing, the output voltage is clamped al [VZ1 + 0.7] volts. The 0.7-volts factor represents the normal junction potential across the forward biased diode CR2. The situation reverses on negative swings of the output signal. The output signal is clamped to [−(VZ2 + 0.7)] volts.

Square waves from sine waves

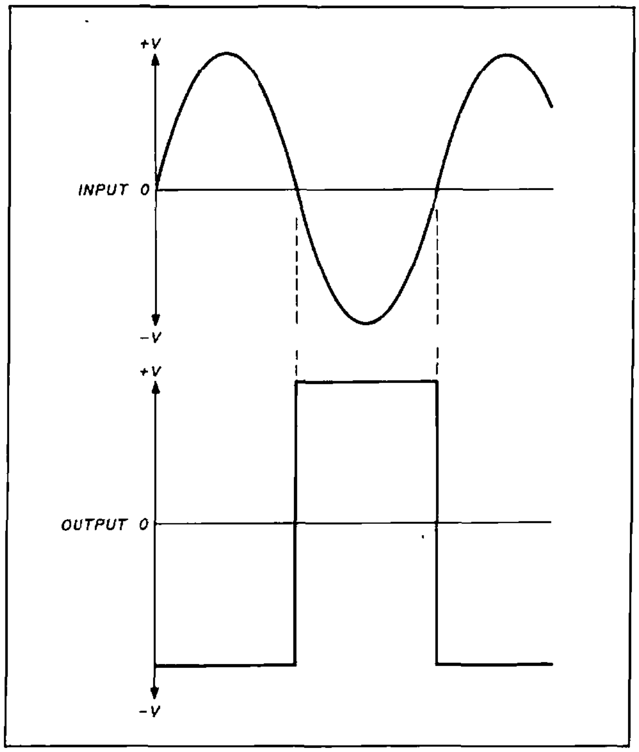
Figure 6 shows a method for converting sine waves to square waves. The circuit is shown in **Figure 6A**, while the

FIGURE 6A



Sine to square wave circuit.

FIGURE 6B



Graphical representation of the waveforms.

waveforms are shown in **Figure 6B**. The circuit is an operational amplifier connected as a comparator. Because the op amp has no negative feedback path, the gain is very high (Avol). In typical op amps, gains of 20,000 to 2,000,000 are found. Thus, a voltage difference across the input terminals ot only a few millivolts will saturate the output. From this behavior you can understand the operation of the circuit, and the waveform in **Figure 6B**.

The input waveform is a sine wave. Because the noninverting input is grounded (**Figure 6A**), the output of the op amp is zero only when the input signal voltage is also zero. When the sine wave is positive, the output signal will be at −Vo; when the sine wave is negative, the output signal will be at +Vo. The output signal will be a square wave at the sine wave frequency, with a peak-to-peak amplitude of [(+Vo)−(−Vo)] . hr

HAM RADIO *cumulative index*

1985-1989

ANTENNAS AND TRANSMISSION LINES

general

hf antennas

vhf antennas

matching and tuning

towers and rotators

transmission lines

AUDIO

COMMERCIAL EQUIPMENT

COMPUTER-AIDED DESIGN

CONSTRUCTION TECHNIQUES

DIGITAL TECHNIQUES

FEATURES AND FICTION

FILTERS

FM AND REPEATERS

HAZARDS

INTEGRATED CIRCUITS

KEYING AND CONTROL

MEASUREMENTS AND TEST EQUIPMENT

MISCELLANEOUS TECHNICAL

NOVICE READING

OPERATING

OSCILLATORS

PACKET

POWER SUPPLIES

PROPAGATION

RECEIVERS AND CONVERTERS

general

hf

vhf

RTTY

SATELLITES

SEMI-CONDUCTORS

SINGLE SIDEBAND

SOFTWARE

TELEVISION

TRANSMITTERS AND POWER SUPPLIES

general

hf

(continued on page 97)

(continued from page 92)

TROUBLE-SHOOTING

VHF AND UHF

general

antennas

receivers and converters

transmitters

microwave techniques

Elmer's Notebook

Tom McMullen, W1SL

EXPLORING MAGNETISM

In last month's column I mentioned an experiment using bell wire, a compass, and a battery in connection with magnetic fields. It occurred to me later that perhaps some of you had never performed this experiment, or had never heard of it. It's sometimes good to go back to basics and look at the principles that make our world of electronics possible.

The equipment

The equipment list for this experiment isn't very long, and the cost involved is small. If you're a good scrounger or pack rat, you may not need to spend a cent.

You'll need some wire — about 5 or 6 feet of bell wire will do. (Bell wire is sometimes used to wire up door bells, hence its name.) If you buy it, you'll probably have to purchase a roll of 25 or 30 feet. You might have better luck in a hardware or electrical store than at an electronics shop. Bell wire is solid copper covered with insulation. If you can't find bell wire, use solid copper wire of approximately 20 or 22 gauge, with either an enamel coating or plastic insulation. (Twenty-gauge wire is approximately the same diameter as the lead in a common mechanical pencil.)

Next, you'll need a power source. A C-size flashlight cell will do nicely. Be sure it's fresh — this experiment soaks up current quickly. You can use an alkaline, carbon zinc, or mercury cell.

CAUTION: *Do not use NiCd cells or any storage battery! The high current capacity of these batteries will cause the wire to overheat quickly and may cause burns.*

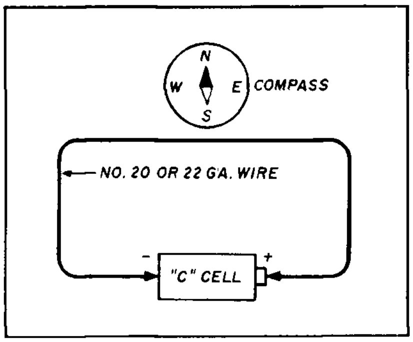
The last item on the list is a compass. Any simple, inexpensive compass, like those used by Scouts or sold by camping outfitters, should work.

After you've collected all the parts, clear a space on a wood (not metal) work surface and try some experiments.

Cut off about 2 feet of wire, and bare the ends for approximately half an inch. If you have enamel insulated wire, you'll need a bit of sandpaper to clean the insulation off.

Place the wire on the table in an oval or rectangle, as shown in **Figure 1**. Place the compass either under or over the wire along the side away from the battery. This stiff wire sometimes tends to flop around a bit, so use a couple of pieces of tape to hold it down.

FIGURE 1



The basic experiment requires a C cell, a piece of wire, and a compass. Tape the wire in place to hold it still, and place a small compass on top of the wire or beside it. Be sure the wire is placed North and South as shown.

If you have a battery holder that the C cell will slip into, use it. Otherwise, you'll have to hold a wire on one end of the cell. Touch the other end of the wire to the positive cap of the cell while you watch the compass. It should swing quickly to a right angle from the wire. Don't hold the wire on the cell any longer than necessary to see what the compass does.

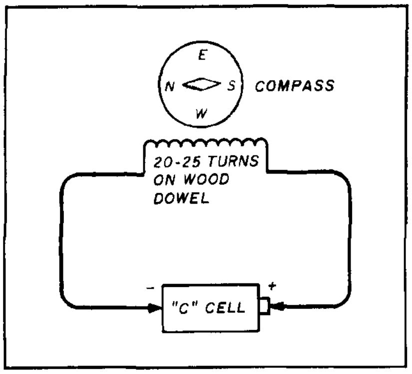
What did that?

When you completed the circuit from one end of the cell to the other, a heavy current started flowing through the wire. Current flow (electron movement) creates a magnetic field and the lines of magnetic force go around the wire. The compass needle aligns with them, just as it does with the earth's magnetic field.

Try it again; but this time reverse the battery. Which way did the compass point? This demonstrates another rule. If you reverse the direction of electron flow, the magnetic field also reverses. Move the compass away from the wire a little bit at a time, and note how far away it is before the field doesn't affect it. Make a note of the distance; I'll refer to it later on.

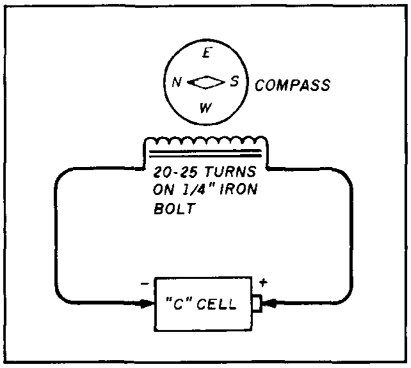
Now let's see what happens when the wire is coiled up, with several turns next to each other. Use a 1/4-inch wooden dowel or stick as a form. Wind 20 or so turns of wire on the dowel, making the turns close to each other. Place this coil on the table, and tape the wires down as before. Put the compass right next to the coil, perhaps on top of it, (see **Figure 2**). Touch the wires to the cells and watch the compass. Which way did it point? It seems to point along the coil, right? Look closely at the coil. If the compass is pointing along the coil, then it's also pointing at right angles to each individual wire in the coil. Perhaps it moved more quickly

FIGURE 2



Wind the wire into a coil around a wooden dowel and place the compass beside it or on top of it. Note the position of the N and S markings and the coil for this experiment.

FIGURE 3



Replace the wooden dowel with an iron bolt and note how much stronger the field is. You may have to move the compass more than a foot away before the field no longer affects it.

this time than it did with the single wire you started with. This tells you that the magnetic field is stronger. How can this be? The current capability of the C cell is still the same, so the answer must be that the lines of force are more concentrated by the wires being so close together.

Next, put some metal in the field and see what it will do. Replace the wooden dowel with a 1/4-inch bolt, (see **Figure 3**). A plain, hardware store soft iron bolt will do (don't use hardened steel). Tape the wires in place, with the compass beside the coil, and touch the wires to the battery. That compass snapped around smartly, didn't it? Move the compass near one end of the bolt and try again. The compass is telling you that the bolt is a magnet. (Even a soft iron bolt will stay magnetized to some extent after the current stops flowing in the coil, so the compass will still point toward the bolt.)

Move the compass away again, and see how far the field makes it move. Compare this with the results of the first experiment. Not only is the field more intense near the coil, but it affects the compass from farther away. Iron or steel concentrates and intensifies the magnetic field. This is one principle that makes electric motors, loudspeakers, power transformers, and hundreds of other devices work.

Another experiment comes to mind, but we'll have to cheat a bit on the equipment list. The compass isn't fast enough to show what will happen. I'll explain why in a moment.

Instead of using the compass as an indicator, get an LED. A plain LED without any resistor in the base will do the trick. Wind a layer of wire on top of the previous winding. If you had 20 turns on the first winding, make this second one twice as large — 40 turns. Remove the insulation from the ends of the wire and connect the LED to the bare ends. Clip lead connections are fine; there's no need to solder them on.

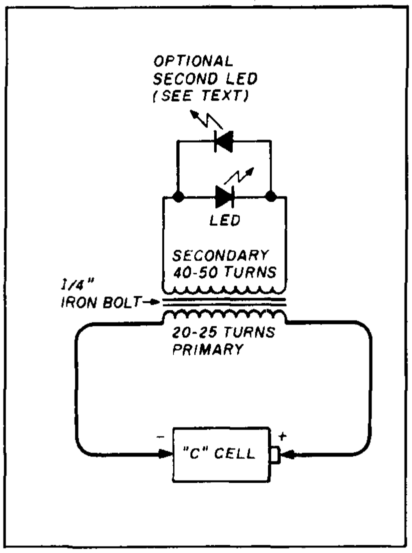
Tape the wires down to hold things steady, and touch the wires to the battery. Watch the LED closely; note whether it flashes when you *touch* the wire, or when you *remove* the wire from the battery. Reverse the connections to the LED and try again. What happened this time? Which flash was brighter? Why didn't the LED stay on? Here's what's going on. This is a very crude transformer (see **Figure 4**). The original winding is the primary; the extra winding you added is the secondary. The bolt serves as the core of the transformer to concentrate the magnetic field.

Current flows when you touch the wires to the battery, generating a magnetic field. This magnetic field cuts across the secondary wires, causing a current flow in that circuit.

The LED is a diode which conducts in only one direction. Depending on the way it was connected in the circuit, it may have flashed when you touched the wire to the battery, or when you removed the wire. When you reverse the diode connections, the effect is the opposite of the first try. If you have two LEDs, you can connect them both in the circuit in parallel, but with opposite polarity. One will flash when you touch the wires, the other when you remove the wires.

A magnetic field induces current flow in wires only when it's moving across the wire (or when the wire is moving through the field). Because the power source is DC, the field builds up and then stabilizes, so you'll see the LED flash while the field is building up. There's no current flow in the secondary after the field stabilizes, so the LED isn't on. When you remove the wire from the battery, the field collapses because there's no electron flow to sustain it. As it collapses, it cuts

FIGURE 4



A simple transformer is made by placing another winding on top of the first one. The second winding has more turns than the first one. You can use one or two LEDs, as explained in the text.

across the secondary wires again. This creates current flow, and the diode will flash (if its polarity is right). By using two LEDs, you can demonstrate that the current flows in one direction as the field builds up and the other direction when the field collapses. The rule that's confirmed here is that the direction of current flow depends upon the direction of movement of the magnetic field relative to the wire.

Now, why is the flash brighter when the wire is removed from the battery? It's a matter of stored energy. The current flow is sustaining the magnetic field as long as the wire is connected to the battery. This is energy being used to keep the field in place, so you can say that some energy is stored in the magnetic field. It's a bit like pressing against a strong spring. As long as you're pushing against the spring,

you're using energy to hold it in place. When you stop pushing, the spring rebounds, and the energy you "stored" there while pushing against it is released by the spring when it returns to the original position.

The stored energy in the magnetic field induces a greater current flow in the secondary winding of the transformer, causing the LED to flash brighter. This is what makes automotive ignition systems work — the stored energy in the coil's magnetic field creates a very large spark when the points open. This is why you'll see a diode connected across the winding of relays used in transistorized equipment. The pulse generated by the relay coil when the circuit is turned off can ruin a sensitive transistor in a microsecond. The diode absorbs most of the energy and saves the transistor.

As I mentioned earlier, the compass isn't useful as an indicator in this experiment. The pulse that lights the LED is so brief that the compass needle doesn't have time to move before the pulse dies out. I had you wind more turns for the secondary of the transformer so the voltage across the winding would be increased. Because the primary winding gets its power from a 1.5-volt cell, and there are always losses in a transformer, a secondary winding of the same number of turns produces much less than 1.5 volts in the pulse. If you have an oscilloscope or can borrow one, you can measure it. But with the inefficient iron bolt transformer core, I'd expect less than 1/2-volt output from a 1:1 winding ratio. By making the secondary winding twice as big, you increase the voltage enough that the LEDs will flash easily — perhaps somewhere near 1 volt peak.

We've just looked at some basic magnetic field principles, using a DC power source. Things work much the same way with AC magnetic fields, but the fields keep changing direction with the frequency of the power source. This is the basis for Amateur Radio communications. The end result of all the circuitry in your transmitter is that an alternating current (radio frequency) in your antenna creates a magnetic field that intercepts another antenna and generates a minute current flow in it. The receiver circuitry attached to that antenna lets the other person hear what you say. It's almost like magic, isn't it?

✓ 140

short circuit

Art Correction

In the October issue the DPDT switches at the top of Figure 1 on page 47 of KD9SV's article "Variable Gain 160-Meter Preamp" were shown incorrectly. They should have appeared as shown in the corrected drawing below.